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NEW CHAIRMAN OF COUNCIL

At the meeting of Council held on Monday, 12th July, Mr. E. Munro Runtz, F.R.I.C.S., was unanimously elected Chairman of the Council for the ensuing year, in succession to the Right Honble. the Earl of Radnor, K.C.V.O.

Mr. Runtz previously held this office for the year 1952–53.

VISIT TO LONGFORD CASTLE

One of the most enjoyable of all the functions of this Bicentenary year took place on Saturday, 3rd July, when, by the kind permission of the Earl and Countess

Longford Castle

The host and hostess

of Radnor, a party of over 200 members of Council, Fellows and Staff of the Society visited their home at Longford Castle, near Salisbury, which was also the home of Lord Radnor's ancestor, Jacob, Viscount Folkestone, the Society's first President.

The weather had been fitful and showery in the morning, culminating in a torrential storm in the early afternoon, but fortunately the rain ceased just as the visitors arrived, and at times the sun came out and enabled them to enjoy a stroll in the famous gardens and admire the surrounding scenery of river and park.

The Castle itself is of unusual design. It was built in 1591 by Sir Thomas Gorges to the plan of John Thorpe, and is in the form of a triangle with three corner towers. It has been the home of the Pleydell-Bouverie family since 1717, and its treasures were of particular interest on this occasion because of the connection of many of them with the first Viscount Folkestone and the first and second Earls of Radnor, whose features are known to present-day members of the Society through their portraits on the walls of the Lecture Hall (all three of them appear in Barry's group of early members of the Society).

But this visit was far more than a sightseeing tour. The gracious and hospitable spirit of the host and hostess, and of the members of their family who supported them, pervaded the whole party and made all the guests feel truly at home—not least when enjoying the delightful tea which had been provided for them.

The Society is indeed deeply indebted to Lord and Lady Radnor for their kindness in making this very special contribution to the pleasures of a memorable year, and for giving a new intimacy to a family association with the Society which goes back to the Society's very beginnings.

(*The two photographs reproduced above were taken by Mr. A. E. Hartley.*)

FELLOWS' SOIRÉE

About 150 Fellows and their guests attended the Soirée which was held at the Society's House on Wednesday, 30th June. The evening's entertainment included a number of short films of the various Bicentenary functions and of certain Royal visits to the Society; recorded selections from the music played at the Church of St. Martin-in-the-Fields at the Thanksgiving Service on 22nd March; and an exhibition of the addresses of congratulation presented to the Society, together with photographs of the Bicentenary functions. There was also a small display of eighteenth-century drawings.

PRESENTATIONS TO STAFF

An informal ceremony took place on Monday, 12th July, at the commencement of the Council Meeting, when eight members of the Society's staff who had served twenty-five years or more attended to receive an inscribed copy of the new History of the Society. It is intended that in future a similar presentation shall be made to individual members on completing twenty-five years' service.

In making the presentation the retiring Chairman, Lord Radnor, said how gratifying it was to find so much long service in these comparatively unstable times, and he felt that perhaps the secret lay in the understanding that existed between employer and employed and in the appreciation of the problems of each. In this Bicentenary year it was appropriate that loyal service to the Society should be recognized, and it gave him great pleasure, on behalf of the Council, to present a small token of their esteem to the members of staff concerned.

The list of recipients, in order of seniority of service, is as follows:

Mr. C. Elton (35 years).
Mr. H. J. Baker (32 years).
Mr. J. H. Flanders (32 years).
Mr. F. A. Wheeler (29 years).
Mr. A. G. Barnes (28 years).
Mr. J. Samson (28 years).
Mr. G. A. Nicholls (26 years).
Mr. I. Jacobs (25 years).

MEETING OF COUNCIL

A meeting of Council was held on Monday, 12th July, 1954. Present: Mr. E. Munro Runtz (in the Chair); Mr. F. H. Andrews; Sir Alfred Bossom; Sir Frank Brown; Mr. Robin Darwin; Mr. John Gloag; Sir Ernest Goodale; Mr. A. C. Hartley; Dr. R. W. Holland; Mr. William Johnstone; Lord Latham; Sir Harry Lindsay; Mr. F. A. Mercer; Sir Francis Meynell; Mr. J. A. Milne; Mr. O. P. Milne; the Earl of Radnor; Mr. E. M. Rich; Professor A. E. Richardson;

Mr. A. R. N. Roberts; Mr. Gordon Russell; Sir Harold Saunders; Sir Selwyn Selwyn-Clarke; Sir John Simonsen; Mr. William Will; Sir Griffith Williams; Mr. J. G. Wilson, and Sir John Woodhead; with Mr. K. W. Luckhurst (Secretary).

ELECTIONS

The following candidates were duly elected Fellows of the Society:

Abraham, Victor Hugo, Ph.C., M.P.S., Reading, Berks.
Adair, Gilbert Smithson, M.A., F.R.S., Cambridge.
Aitken, David William, A.R.I.B.A., Kuwait, Persian Gulf.
Anthony, Wilfred Mathai, Hatch End, Middx.
Auber, Lewis, Ph.D., F.R.S.E., Leeds, Yorks.
Beswick, John Reginald, M.A., London.
Blair, Lawrence William, Montreal, Quebec Province, Canada.
Blomfield, Leslie Arthur Albert, Lusaka, Northern Rhodesia.
Bottom, William Walter, Armagh, Northern Ireland.
Buchanan, Charles, London.
Cairns, John Edwin Ingliston, M.Sc., Ph.D., A.M.I.E.E., Chalfont St. Peter, Bucks.
Colley, Charles Raymond, B.Sc., A.C.G.I., Surbiton, Surrey.
Colton, Cyril Hadlow, Esher, Surrey.
Cooper, John W., London.
Dimoline, Brigadier Harry Kenneth, C.B.E., D.S.O., T.D., Kuala Lumpur, Malaya.
Dixon, Hugh Hume, M.A., M.I.C.E., M.ASCE., Checkendon, Oxon.
Dogra, Lt.-Colonel Jaswant Rai, M.D., Ch.B., Bombay, India.
Elgin, Leonard Julius, A.M.I.C.E., London.
Ellis, Miss Nancy Lorna, South Hurstville, New South Wales, Australia.
Fermor, Lady Frances Mary, Horsell, Surrey.
Garment, Clifford Charles, London.
Haddow, Denis Foster, Stoke-on-Trent, Staffs.
Hally, George, M.I.Mech.E., Walton-on-Thames, Surrey.
Hann, Victor Adams, B.S., St. Davids, Pennsylvania, U.S.A.
Hartmann, Raymond Theobald, M.A., London.
Heynes, Peter Lawrence Roche Burch, Birmingham.
Hill, Sir Reginald Herbert, K.B.E., C.B., London.
Hin, Lim Theng, Penang, Malaya.
Hock, Chan Eng, Penang, Malaya.
Hodgson, John Joseph Trevor, Morecambe, Lancs.
Jones, Arthur Charles, F.I.C.S., Snaresbrook, Essex.
Kao, Wilson Samuel, Singapore.
King, John Arthur Clement, A.M.I.E.E., Kuwait, Persian Gulf.
Lenegan, James, Altrincham, Cheshire.
Lester, Jack, London.
Levin, Isaac, B.Eng., B.Sc., M.I.C.E., High Wycombe, Bucks.
Lockton, William Henry, A.M.I.E.E., Farnborough, Hants.
Mansell, William Arthur Byram, Sydney, New South Wales, Australia.
Margerison, Thomas Alan, B.Sc., Ph.D., Swanley, Kent.
Morgan, Gwyn, B.Sc., M.I.M.E., Como, Perth, Western Australia.
Presdee, Glyn William, Salisbury, Wilts.
Salveta, Miss Adelina Libera, Sheffield.
Stobart, George Ambrose, Burutu, Southern Nigeria.
Storey, Thomas, Bramhall, Cheshire.

Sweeney, James Johnson, A.B., New York, U.S.A.
Talmadge, Reginald Henry, Burgess Hill, Sussex.
Tavener, Robert, Eastbourne, Sussex.
Walker, Peter Russell, T.D., F.R.I.B.A., Colchester, Essex.

The following was admitted under Bye-Law 66:
Brown University, Providence, Rhode Island, U.S.A.

R. B. BENNETT EMPIRE PRIZE

In accordance with a recommendation of the Commonwealth Section Committee regarding this award, a name was agreed upon for submission to H.R.H. the President.

EXAMINATIONS IN WEST AFRICA

It was agreed to enter into a relationship with the recently appointed West African Examinations Council for the purpose of organizing special examinations in commercial subjects for West African students.

OTHER BUSINESS

A quantity of financial and other business was transacted.

ROYAL DESIGNERS FOR INDUSTRY

Two interesting functions have recently been held by the Faculty of Royal Designers for Industry. The first was a luncheon, held on Tuesday, 24th June, at Kettner's Restaurant, in honour of the Society's Bicentenary. The guests were the Earl of Radnor, Chairman of Council; Mr. Misha Black, President of the Society of Industrial Artists; Mr. W. J. Worboys, Chairman of the Council of Industrial Design; and the Council representatives on the R.D.I. Joint Committee, Mr. F. H. Andrews, Sir Alfred Bossom, Bart., Mr. F. A. Mercer, and Mr. E. Munro Runtz. In addition there were 17 R.D.I.s present, together with Mr. K. W. Luckhurst, who is Secretary of both the Society and the Faculty.

An evening reception was held on Thursday, 8th July, at the Society's House. About 90 people were present on this occasion and were received by Sir Francis Meynell, the Master of the Faculty, and Lady Meynell. They were entertained during the evening with poetry readings by Miss Margaret Rawlings and songs by Miss Jennifer Vyvyan. These receptions are an annual function of the Faculty, the first of them, in 1950, being honoured by the presence of Her Majesty The Queen, then Her Royal Highness Princess Elizabeth, President of the Society.

BICENTENARY COMPETITION

'LIFE IN 2000 A.D.'

The number of entries received for the Bicentenary Competition, the closing date for which was 30th June, is 183. They comprise 159 essays, 17 drawings and paintings, and 7 models.

The entries have been classified as follows:

Agricultural	11
Building and Planning	19
Domestic	18
Education	26
Industry	24
Medical	12
Recreation, Social and Cultural	21
Transport and Communications	52

A panel of Judges has been appointed in each section, and a list of their names is given below.

Judging is now in progress, and it is hoped that it will be possible to announce the results by the end of September.

List of Judges:

Agriculture: Sir William Ogg, M.A., Ph.D., LL.D., Director, Rothamsted Experimental Station (*Chairman*); Viscount Hudson, P.C., C.H.; W. H. Cashmore, B.A., N.D.A., Director, National Institute of Agricultural Engineering.

Building and Planning: Sir Alfred Bossom, Bt., M.P., F.R.I.B.A. (*Chairman*); Sir Hugh Casson, R.D.I., M.A., F.R.I.B.A.; Sir George Burt, M.I.C.E., Director, Messrs. John Mowlem & Co., Ltd.

Domestic: Miss Anna Zinkeisen, R.O.I., R.D.I. (*Chairman*); H. P. Juda, Editor, *The Ambassador*; Miss Elizabeth Craig.

Education: Sir Griffith Williams, K.B.E., C.B., lately Deputy Secretary, Ministry of Education (*Chairman*); Sir Richard Southwell, M.A., LL.D., D.Sc., F.R.S.; Miss G. M. Colton, B.A., Headmistress, City of London Girls' School.

Industry: Sir Harold Saunders, B.Sc., F.C.G.I., late Comptroller-General, Patents Designs and Trade Marks (*Chairman*); Lord Halsbury, Managing Director, National Research Development Corporation; Sir Graham Cunningham, K.B.E.

Medical: Sir Charles Dodds, M.V.O., D.Sc., Ph.D., M.D., F.R.S., Courtauld Professor of Biochemistry, University of London (*Chairman*); Sir Selwyn Selwyn-Clarke, K.B.E., C.M.G., M.C., M.D., a Principal Medical Officer, Ministry of Health; Sir Henry Cohen, M.D., Professor of Medicine, University of Liverpool.

Recreation, Social and Cultural: Sir Stephen Tallents, K.C.M.G., C.B., C.B.E. (*Chairman*); Mrs. Mary Adams, O.B.E.; Sir Wavell Wakefield, M.P.

Transport and Communications: A. C. Hartley, C.B.E., B.Sc., F.C.G.I. (*Chairman*); Sir John Elliot, Chairman, London Transport Executive; J. D. McGee, O.B.E., M.Sc., Ph.D.; W. H. Glanville, C.B., C.B.E., D.Sc., Ph.D., Director of Road Research, D.S.I.R.; B. N. Wallis, C.B.E., D.Sc., F.R.S., R.D.I., Chief of Aeronautical Research & Development, Vickers-Armstrongs, Ltd.

MINERAL RESOURCES OF THE BRITISH COMMONWEALTH: SOME RECENT DEVELOPMENTS

A paper by

R. W. WILLETT, M.Sc., F.G.S.,

Geological Liaison Officer, British Commonwealth Scientific Office, London, read to the Commonwealth Section of the Society on Thursday, 11th March, 1954, with Professor W. J. Pugh, O.B.E., D.Sc., F.R.S., Director of the Geological Survey of Great Britain, in the Chair

THE CHAIRMAN: I am glad to have been invited to take the Chair at this lecture and to have been given the opportunity of introducing to you my friend and colleague, Mr. Willett. He is a member of the staff of the Geological Survey of New Zealand, seconded for service in London as Geological Liaison Officer for the British Commonwealth. This is a comparatively new office recommended by the British Commonwealth Specialist Conference on Mineral Resources and Geology which was held in this country in 1948. The purpose of the recommendation was to secure effective liaison in matters relating to mineral resources and geology for all members of the Commonwealth. Mr. Willett took up this office in 1951.

His work consists mainly of the preparation of reports upon the mineral resources of the British Commonwealth, and of providing relevant information to Government departments and others both in this country and overseas; and of giving information, too, about matters of general geological interest. He is a personal link between the geologists, and particularly the Geological Surveys, of the Commonwealth countries, and is to be congratulated on the success of his efforts during the past three years. He has a wide knowledge of economic geology, and is well qualified to talk to us about the mineral resources of the British Commonwealth.

This is a particularly appropriate subject for this Society, concerned as it has been for about two hundred years with the encouragement of science and technology. Let me remind you that minerals are the basis of our industrial development and also of our defence against aggression. The more we manufacture, the greater is the demand upon mineral resources; the greater the demand the greater is the depletion of unrenewable resources and the greater is the need to search for new ones. That search necessitates knowledge of their occurrence, distribution and mode of origin; in other words the application of geological methods and principles. You will find from Mr. Willett's lecture that the British Commonwealth is particularly rich in mineral resources and in addition is one of the greatest potential sources in the world for the development of new mineral resources.

The following paper was then read:

THE PAPER

The sharp increase in consumption of mineral ores since the First World War and particularly the fantastic consumption of an increasing variety during and since the Second World War have brought about several attempts to assess the future position. National stock-takings have pointed to important deficiencies and have underlined the fact that no one nation or group of nations is completely self-sufficient. From the point of view of mineral resources alone, the British Commonwealth as a group of nations is probably closer to potential self-sufficiency than any other single nation or group of nations, but its deficiencies, although not numerically great, are fairly critical, particularly in the field of minor metals and certain newcomers to the ferro-alloy group—both of which are rapidly increasing in use—where the impact of these deficiencies is much greater. Even countries of former self-sufficiency have become importers, for consumption has now outstripped production: for example, the United States has changed from exporter to importer of petroleum, copper and zinc. The United States is not quite comparable with the British Commonwealth, for it has a great internal industrial capacity served by a huge domestic supply of raw materials, particularly mineral ores, whereas the British Commonwealth contains within it two industrial nations: the United Kingdom, largely dependent upon overseas mineral resources, and Canada, with almost self-sufficiency of mineral resources. To a lesser extent Australia and South Africa fall into the Canadian group. The British Commonwealth nations, if regarded as an economic block, form a highly industrialized group with almost a self-sufficiency of mineral resources; in fact, further exploration and development could well result in this self-sufficiency approaching 100 per cent.

If we are to make complete and mutual use of the mineral resources within the group known as the British Commonwealth, then some stock-taking of our present resources position and our future requirements should be undertaken. The United States has already done this in the Paley Report, in which the British Commonwealth is noted, but a similar report on the British Commonwealth alone is needed.

It is not, however, the purpose of this paper to supply such a report, or even the framework of it, but rather to discuss the geological and geographical distribution of mineral resources in the British Commonwealth and, at the same time, to discuss a group of selected critical minerals that for various reasons are important to-day. This paper will highlight some recent developments in connection with the resources of the ores of important metals and non-metals that either can be termed 'strategic' or have recently come into prominence because of new developments in metal alloys or electronics. To attempt a complete picture of the mineral resources of the British Commonwealth would in the time available be an unworthy treatment of such an important subject.

The advance of technology has created a demand for a far greater variety of metals, both in the pure state and as alloys, than existed say fifteen years ago.

In particular this demand has affected what were formerly known as the minor metals and some of the rarer metals. At the same time the common non-ferrous and ferro-alloy metals have widened their sphere of usefulness, and consumption has moved up to levels almost unthought of two decades ago. In spite of an increased search within the British Commonwealth there is still a deficiency of certain of these metallic ores. The increase in the use of the heavy non-ferrous metals has been steady and production has held a fairly steady relationship to measured and indicated reserves, but the demand for the additive metals, as a result of the wide use of specialized alloys, has climbed steeply and has in most cases caused an intense search for fresh natural reserves or new by-product sources.

During the course of this paper it will be noted that reserves of ore are referred to as 'measured' 'indicated' and 'inferred'; these terms are now widely accepted, and are defined briefly thus: 'measured' reserves are those computed from outcrops, trenches, workings and drill holes, and the grade is computed from detailed sampling; 'indicated' reserves are those for which tonnage and grade are computed partly from specific measurements, samples or production data, and partly from projection for a reasonable distance on geological evidence; 'inferred' reserves are those based largely on broad knowledge of the geological character of the deposit and for which there are few, if any, samples or measurements.

Mineral groups

For the purposes of discussion the metallic and non-metallic ores have been grouped under four major headings, thus:

1. Fertilizer group.

2. Energy producing group.

3. Metallic group: (i) Iron ores, (ii) Ferro-alloy. (iii) Non-ferrous, (iv) Industrial chemical minerals, (v) Minor metals, (vi) Precious metals.

4. Non-metallic group: (i) Metallurgical and chemical, (ii) Structural minerals, (iii) Ceramic, (iv) Abrasive.

In this paper only a selection of the more interesting and critical minerals belonging to the fertilizer group, certain sections of the metallic group, and the non-metallic group, are discussed.

PRODUCTION AND GEOGRAPHICAL DISTRIBUTION

The major mineral ore producing countries of the British Commonwealth, whose production, excluding the energy fuels and precious metals, is a major factor in their domestic and export economy, are Canada (£304 million sterling annually), Australia (£53 million), South Africa (including South West Africa) (£53 million), and India (£38 million). Figure 1 shows the whole picture.

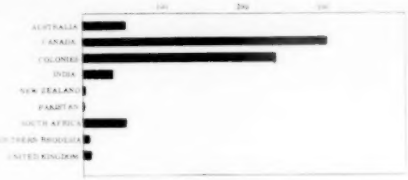

FIGURE 1. *Annual mineral production in £ million (excluding coal, petroleum and precious metals).*

The distribution of reserves and resources of selected important minerals is presented in Table I. In this table an attempt is made to indicate the relative size of the resources of these selected mineral ores in the countries of the British Commonwealth. It will be seen from the table that the greatest variety of mineral resources regarded as abundant is found in Canada, particularly iron and the heavy non-ferrous minerals. Over the last decade petroleum, and recently potash, have climbed into this grouping. Australia and the United Kingdom are able to contribute less than half the resources grouped as abundant of Canada, Australia contributing the metallic groups and the United Kingdom the non-metallic and the important minor metal germanium. The Colonial Territories follow next with important minerals, graded as abundant, which include almost all the world's resources of niobium, bauxite and tin. South Africa has five mineral ores falling into the abundant group, namely phosphate, chromium, iron ore, titanium (as titaniferous iron ore) and beryllium. The remainder are fairly well distributed over the remaining British Commonwealth countries.

The following list and Figure 2 show the geographic distribution of these selected mineral resources regarded as occurring in abundance:

Australia
- Coal
- Iron
- Oil Shale
- Lead
- Gypsum

Canada
- Potash
- Sulphur-bearing minerals
- Petroleum
- Iron
- Cobalt
- Copper
- Lead
- Zinc
- Nickel
- Titanium
- Barium
- Selenium
- Gypsum

Colonial Territories
- Phosphate
- Petroleum
- Niobium
- Aluminium (Bauxite)
- Tin

India
- Iron
- Titanium
- Mica

TABLE I. MINERAL RESOURCES IN THE COMMONWEALTH

	Australia	Canada	Ceylon	Colonies	India	New Zealand	Pakistan	South Africa	Southern Rhodesia	United Kingdom
Fertilizer group										
Potash	L	A	N	N	L	N	N	N	N	A
Phosphate	N	N	N	A	L	N	N	A	A	N
Sulphur minerals	L	A	N	L	L	N	N	A	L	L
Energy group										
Coal	A	A	N	N	A	L	N	A	L	A
Petroleum	N	A	N	A	L	N	L	N	N	N
Oil Shales	L	N	N	N	N	L	N	N	N	L
Iron ores	A	A	N	A	A	L	N	A	A	A
Ferro-alloy group										
Chromium	L	A	N	L	L	N	A	A	A	N
Cobalt	L	A	N	A	N	N	N	L	N	N
Manganese	A	N	N	A	A	N	N	A	N	N
Molybdenum	L	L	N	N	N	N	N	L	N	N
Niobium	L	L	N	A	N	N	N	L	L	N
Tungsten	A	L	N	L	N	L	N	A	A	N
Vanadium	N	N	N	N	N	N	N	L	L	N
Non-ferrous group										
Aluminium	A	N	N	A	A	N	N	N	N	N
Copper	A	A	N	A	L	N	N	A	N	N
Lead-zinc	A	A	N	A	N	N	N	L	N	L
Nickel	N	A	N	L	N	N	N	L	L	N
Tin	L	L	N	A	N	N	N	L	L	N
Titanium	A	A	N	N	A	A	N	A	L	N
Minor metals group										
Beryllium	L	N	N	L	A	N	N	A	A	N
Germanium	L	N	N	N	N	N	N	N	N	A
Lithium	L	L	N	A	L	N	N	L	A	N
Selenium	A	A	N	N	N	N	N	N	A	N
Non-metallic group										
Gypsum	A	A	L	A	A	N	A	A	N	A
Mica	L	L	N	A	A	L	N	A	L	N

A : adequate, or potentially adequate resources, or an actual or potential large surplus available for export.
L : low ; a deficiency made up by import, or where there is negligible local consumption it indicates a minor export.
N : negligible ; exploitable deposits are very small or at most there is no more than a token output. No reserves of any significance.

New Zealand
Titanium (*no production*)

Pakistan
Chromium
Gypsum

South Africa (including South-West Africa)
Phosphate
Tin
Chromium
Titanium (*no production*)
Beryllium

Rhodesia and Nyasaland
Chromium
Copper
Beryllium

United Kingdom
Potash
Iron
Germanium

The above geographical distribution of the chief mineral resources of the British Commonwealth follows, as would be expected, the distribution of certain geological formations.

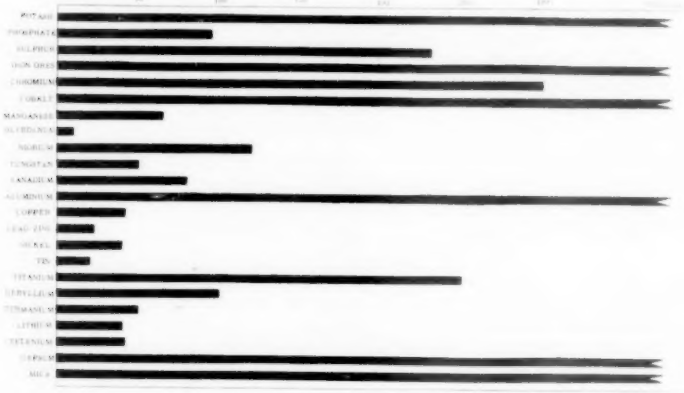

FIGURE 2. *Estimated life (in years) of selected mineral resources in the British Commonwealth based on the 1950 rate of production*

GEOLOGICAL DISTRIBUTION

By far the greater part of the metallic ores are confined to the Pre-Cambrian shield rocks that are exposed in the continental areas of the British Commonwealth, which, covering as it does a large part of the earth's surface, is made up of a wide variety of geological formations. It is the nature and extent of these formations, particularly those of the Pre-Cambrian, that control the presence or absence of economic mineral deposits.

Pre-Cambrian shield rocks

The non-ferrous and ferro-alloys minerals and the greater part of the iron ore deposits are found in the rocks of the Pre-Cambrian shield. These rocks,

including sedimentaries, volcanics and basic intrusions, form that part of Canada which extends from the Labrador seaboard to a line north from Lake Winnipeg to Great Bear Lake, where they disappear under a huge thickness of younger sedimentary rocks which, in turn, extend west to the Rocky Mountains. The Pre-Cambrian rocks thus cover the coast of Labrador and the provinces of Quebec, Ontario, Manitoba and the North-West Territories, a total area of about two million square miles, and contain, as far as Canada is concerned, the metallic ore resources of that country, except for some non-ferrous ore deposits associated with intrusive rocks of the Rocky Mountain Cordilleran region.

The exposed rocks of South Australia, Western Australia and the north of Northern Territory are made up of similar Pre-Cambrian rocks and again, as in the case of Canada, carry the iron ores and the non-ferrous and ferro-alloy ore resources of Australia.

In Africa, south of the Sahara, Pre-Cambrian shield rocks appear in the western coastal area of British West Africa, through the Belgian Congo into Northern and Southern Rhodesia, and form the basement rocks of the Union of South Africa. The great copper deposits of the Belgian Congo and Northern Rhodesia, the 'Copper Belt', belong to rocks of this age; similarly, the relatively less extensive copper ores of Southern Rhodesia and South Africa also occur in these shield rocks. Pre-Cambrian rocks appear in patches in British East Africa, frequently carrying important metallic ore deposits.

The Pre-Cambrian shield forms the basement of the Indian subcontinent; it is distributed over the whole area, crops out in numerous localities and carries the metallic and non-metallic ore resources of India, the important copper, iron, manganese and mica deposits.

Strangely enough, part of the European Pre-Cambrian shield extends westward into the Highlands of Scotland, but here does not appear to carry any economic mineralization. Associated with these Pre-Cambrian rocks are large and important ultra-basic and basic intrusions which in many places carry important minerals, such as the chromites of Southern Rhodesia, South Africa and Pakistan, and the asbestos deposits of Canada, India, Pakistan, Southern Rhodesia and South Africa. A point of interest is that the great metallic ore deposits of the rest of the world lie within Pre-Cambrian shield rocks in the United States, Brazil, the U.S.S.R. and Scandinavia.

Later Formations

A vast thickness of sedimentary rocks ranging in age through the geological column covers the prairie provinces of Canada, lapping the Pre-Cambrian shield in the east and turned up against the Rocky Mountain Cordilleran region in the west. These rocks carry coal, petroleum and non-metallic ores like salt and potash. The sedimentary rocks of Australia are folded round the edge of the Pre-Cambrian shield and form the coastal strip that carries the energy minerals, coal in the east and now petroleum in the west. In South Africa these rocks cover the greater part of the Pre-Cambrian basement and carry energy and non-metallic ores. In Rhodesia the sedimentary rocks lap on the central area of the

metallic-ore-bearing Pre-Cambrian rocks but are in the main of less economic significance except for coal and some other non-metallic ores. Likewise in British West Africa the thin strip of sedimentary rocks is of no particular economic significance. Over the Indian subcontinent sedimentary rocks and associated volcanics cover the great part of both India and Pakistan, and contain energy and non-metallic ores.

Geological exploration of these large areas of Pre-Cambrian rocks has yielded the important metallic ores, and it is these rocks—about which, particularly those in Africa, Australia and Canada, really little is known—that must hold the future resources. The same is true of the sedimentary rocks, where persistent and patient exploration has resulted in oil and potash in Canada, oil in Australia and phosphate in Rhodesia and British East Africa.

FERTILIZER MINERALS

Potash

The British Commonwealth resources of potassium-bearing minerals have only become significant over the past decade. Previously, practically the whole British Commonwealth was dependent upon sources outside its boundaries for potash, India being the only Commonwealth country with any significant domestic production. Since 1939 extensive potash deposits have been found and investigated in Australia, Canada and the United Kingdom. In Australia, the extensive alunite deposits of Western Australia were worked during 1939–49 for their potassium content, but in 1949 these operations were discontinued on economic grounds and Australia again became fully dependent upon overseas sources for all potash requirements. In 1939, during oil-drilling operations in Yorkshire, England, potash-bearing beds were located at a depth of 3,600 feet which have, on further investigation, proved to contain a most valuable tonnage, and plans for the extraction of this potash are being vigorously pushed ahead. In Canada a much more recent development has been the discovery of extensive potash beds at several points extending in a south easterly direction from Unity in the west of Saskatchewan to Young in the east. The Canadian deposits, averaging 11 feet in thickness like those of England, lie at depths over 3,000 feet and again the problem of economic recovery is an important factor in their development. Before these discoveries in Canada and the United Kingdom the potash resources of the British Commonwealth were not important, but now the development of these resources would carry the British Commonwealth some distance towards self-sufficiency. Nevertheless, on a world scale the British Commonwealth resources are still not large particularly when compared with the vast resources of Europe (Germany, France, Spain and Russia) and Transjordan.

Phosphate

Phosphate deposits are widely distributed throughout the British Commonwealth but only in certain parts are they large enough to be of economic importance. Viewed as a whole the resources are large but generally are some distance

from the centre of use. Rock phosphate is largely confined to the Colonial Territories of the Pacific and Indian Oceans, particularly in the south west Pacific, where the largest rock phosphate deposits occur on Nauru and Ocean Islands. Apatite deposits are confined to South Africa, Southern Rhodesia and Uganda, and in Southern Rhodesia and East Africa plans for the development of these new found deposits are well advanced. This distribution means that Australia and New Zealand are able to draw their supplies of rock phosphate from Nauru and Ocean Islands. South Africa at present draws its main supplies of raw rock phosphate from Northern Africa, only a part of its domestic deposits of rock phosphate being used for the local market as a fertilizer for direct application. Plans are at present under way for the manufacture of super-phosphate using the local apatite in Southern Rhodesia and British East Africa. India and Pakistan have no extensive deposits of phosphate and are dependent upon imported rock phosphate and super-phosphate. Canada also has no economic phosphate deposits, the source of supply being the United States and to a lesser extent the British West Indies.

The Colonial Territories, Nauru, Ocean and Christmas Islands, are responsible for nearly 95 per cent of the British Commonwealth phosphate production. The remaining 5·4 per cent comes from the Union of South Africa (3·0 per cent), the Seychelles Islands (0·6 per cent) and the rest of the Commonwealth (each individually less than 0·5 per cent).

The chief development of phosphate deposits in the British Commonwealth is at present confined to the rock phosphate deposits found in the Colonies (Nauru, Ocean and Christmas Islands) and to the Seychelles Islands, the largest guano producer. Apatite deposits are not yet developed to any great extent anywhere. The total reserves are likely to be increased when investigational work in Southern Rhodesia and Uganda is completed, but this concerns apatite only and there is no evidence to suggest that the reserves of rock phosphate will be increased. With 95 per cent of the present Commonwealth production coming from three islands, Nauru, Ocean and Christmas, all of which is consumed by the adjacent countries, particularly Australia and New Zealand, it means that other agricultural countries of the Commonwealth are all dependent upon non-Commonwealth sources. Consequently the projected development of domestic phosphate deposits in Africa is of paramount importance to the Commonwealth as a whole.

IRON

The iron ore resources of the British Commonwealth make up 47 per cent of the world's total and are concentrated in Southern Rhodesia, South Africa, India, the United Kingdom, Canada, Australia and the Colonial Territories, in that order. The most important high grade ores are those of Canada and Australia, whereas the remainder, chiefly those resources of India, South Africa, Southern Rhodesia and the United Kingdom, are lower grade, being made up of bog iron ores, titaniferous ores, chromiferous and manganiferous ores.

The most important recent happening in the exploration and development of iron ore deposits has been the opening up of the Labrador deposits in eastern

Canada. These deposits have been prospected in some detail over a distance of 300 miles from Seven Islands north to the eastern border of Quebec. The productive zone so far found is 90 miles long but lies within a potentially favourable length of 225 miles of iron ore formation. These deposits lie in rocks of Pre-Cambrian age and have an iron content of 30 to 40 per cent. Concentrations of 55 to 65 per cent within the iron formation contribute the economically significant deposits. In addition 220 million tons of taconite averaging 40 per cent iron ore are available but not likely to be developed in the foreseeable future in view of the abundance of natural ores.

Under present mining systems the reserves available are 56 million measured tons, 112 million indicated tons and 1,176 million inferred tons. The average grade is 51 per cent, which represents 685 million tons of metallic iron.

FERRO-ALLOY METALS

Chromium

Chromium ores are found in Australia and Canada, but in neither country is there any significant production. The Australian reserves are limited and generally low grade: the largest deposit is found in Western Australia and is unsuitable for metallurgical purposes. Canadian deposits are in the main all too small and of too low a grade to be of economic importance, but there are, however, large deposits of low grade ore in Manitoba for which a benefication process has been developed to raise it to metallurgical grade. Apart from South Africa and Southern Rhodesia the important chromium ore deposits are in Pakistan. The ore is of metallurgical quality and forms the country's chief mineral export. India on the other hand has scattered chromite deposits which in sum make up fairly large reserves, but there is great variation in grade. The greater part of Indian production is now consumed locally, and in 1950 India's production was fourth in the British Commonwealth.

Sierra Leone and Cyprus are the only Colonial Territories with important chromite deposits. The former has potential reserves covering an area of 2,000 square miles which are at present under investigation. Present production of about 8,000 tons is limited by the inadequate rail transport and shipping facilities. Cyprus maintains a steadily increasing production, now 18,330 tons. Collectively the Colonies in 1950 produced 26,620 tons, 2·8 per cent of the total Commonwealth production.

The great chromite deposits of the British Commonwealth are therefore those associated with the serpentine rocks of the Transvaal in South Africa and with the Great Dyke in Southern Rhodesia. The reserves in both countries are large, representing a total of about 500 million tons of ore. A large part of the South African chromite is of acceptable chemical grade, and in fact South Africa is at present the only producer of such chrome ore, whereas that of Southern Rhodesia is high grade metallurgical chrome ore.

Cobalt

Cobalt resources of the British Commonwealth are found in Australia, Canada

and Northern Rhodesia, the last named being the chief Commonwealth producer, and second to the Belgian Congo as a world producer. Canadian production is about half that of Northern Rhodesia.

The peak production year over the last decade for the British Commonwealth was 1943, when a production of 1,174 short tons was recorded, Northern Rhodesia making its largest contribution of 1,057 tons that year. Increased production in the next few years can be expected from both Canada and Northern Rhodesia. In Canada exploration of new deposits and erection of a new mill at Brady Lake have shown their effect on production in a sharp rise of 423 tons in 1951. Northern Rhodesia production has also shown a sharp increase since 1948 and this rise should continue with the development. The Chibuluma Mines plan to produce 500,000 lb. of cobalt annually from their copper-cobalt area on the south bank of the Nkana river. A new development is the Kilembi Mine in Uganda, where a copper-cobalt ore of 0·15 per cent cobalt is being developed. Plans allow for the treatment of 2,000 tons of ore daily. The projected increases in production are as follows: Canada, 150 short tons by 1955; Northern Rhodesia, 350 short tons by 1956; and Uganda, 750 short tons by 1955, making 1,250 short tons in all. These developments would more than double the present British Commonwealth production.

Manganese

The manganese resources of the British Commonwealth are almost wholly confined to three countries, the Union of South Africa, India, and the Gold Coast Colony. The respective productions of these countries are similar, and collectively they are responsible for 99 per cent of the British Commonwealth total. The remaining one per cent is made up largely by Australia with minor production from Northern Rhodesia, New Zealand and Fiji.

Increased production in both India and the Gold Coast is dependent on better transport facilities, and an improvement in the railway transportation in India was the cause of the recent sharp rise in manganese ore output. The Gold Coast's output also is limited by the capacity of the railway to the port of Takoradi and berthing accommodation at that port.

The upgrading of low-grade vein ores and reject dumps will make for increased production, and with that in view a considerable amount of research work on ores containing less than 30 per cent manganese is at present under way in India and South Africa, where there are large reserves of low-grade ore, and to a lesser extent in Australia. The United States is the largest importer of manganese ore, and much of it comes from the British Commonwealth, particularly from India and the Gold Coast; consequently increase in steel production in both the United States and the United Kingdom must call for increased manganese production from the Commonwealth. Of the British Commonwealth countries Canada is second to the United Kingdom as an importer of manganese ore.

The manganese reserves of the British Commonwealth are large, the greatest being those of South Africa, India and the Gold Coast, whereas Australia and the Colonies have minor reserves that do not substantially alter the overall picture.

Molybdenum

The British Commonwealth is not a molybdenum producer of any great significance: in 1950 the British Commonwealth produced only 0·2 per cent of the world's total, whereas the United States of America alone is responsible for 93 per cent of the world production. Within the British Commonwealth, Canada and Australia are the only producing countries, and although molybdenite occurs widely in South Africa there has as yet been no significant development or production.

Reserves of molybdenite are not extensive, although those of Australia are probably the greater and offer a greater potential for increased production. Production of molybdenite, like other minor metals, directly reflects the level of overseas prices, and as the necessary preliminary prospecting and development are dependent upon the price of the end product, many potential deposits are yet unproved. As the major production of the world is in the hands of two companies the price rarely varies, although recently it has risen three times above the 1948 level, and it has never shown spectacular rises like those of tungsten; as a result there has been little production by small working parties.

Viewed as a whole the molybdenum ore reserves of the British Commonwealth do not hold promise of Commonwealth self-sufficiency. Apart from Canada and Australia, production could be increased by the discovery of a suitable deposit in the potential molybdenite bearing areas of South Africa. Some development promises in the Colonial Territories, particularly Sierra Leone, but beyond these possibilities the present prospects are not encouraging. Such a position suggests that present demand should bring about closer investigation of those areas that are known to carry the ore and this is actually taking place in some areas, but the price and long-term demand are evidently not yet sufficient to bring about the needed vigorous search.

Niobium and tantalum

The chief ores of niobium and tantalum are the minerals columbite and tantalite, which occur as a mixture of niobates and tantalates of iron and manganese. The ore grades from normal columbite ($FeNb_2O_6$), the pure niobate at one end of the scale, to normal tantalite ($FeTa_2O_6$) at the other end. The iron and manganese contents also vary widely. Columbite and tantalite are rarely found in nature as pure minerals, and depending upon which oxide is dominant in the solid solution so the ore of that particular metal is represented. Niobium is classed as being in tight supply in the United Kingdom and in very short supply in the United States.

Niobium- and tantalum-bearing minerals are found and mined to a greater or lesser extent in Australia, Canada, the Colonies (Nigeria, Uganda, Malaya and British Guiana) and Southern Rhodesia. The British Commonwealth production of both niobium and tantalum concentrates is about half the world's total, and 97 per cent of that comes from Nigeria, where the ore is practically all columbite. The British Commonwealth production rose from 491 short tons in 1941 to 2,348 tons in 1944 and has since fallen steadily to 999 tons in 1950. A recent

development has been the indication of the presence of economic quantities of columbite in the Morabisi area of British Guiana where development plans are now under way. In Uganda the recent discovery of the presence of pyrochlore in commercial quantities around the perimeter of Sukulu ring dyke complex has increased the potential resources of niobium, but the problem of separating the pyrochlore still remains. In Northern Rhodesia a preliminary examination of some carbonatite occurrences associated with ring dyke structures has revealed the presence of pyrochlore of such a grade as to encourage further detailed examination. Similar occurrences of pyrochlore are being mapped and investigated in Nyasaland.

The British Commonwealth as a whole is thus the world's major source of niobium and tantalum, a position that is likely to be maintained for some time to come. The development of pyrochlore should enable the Commonwealth to offset any marked rise in the use of niobium, for the East African resources of this niobium-bearing mineral are extensive.

Tungsten

The demand for tungsten has always been associated, in the past, with major wars or crises in international affairs, for the two great production periods have been 1914–18 and 1939–45. Between these periods demand and price have fallen to low levels and, as a result, most of the tungsten ore-producing mines ceased operations. After 1945 the price of tungsten fell, but by 1949 it was climbing again and the present high price level has stimulated production so much that most of the producing areas are now very active. Much of the production comes from parties operating small scale strip workings who are attracted by the high price, for it is only large scale mines that are able to weather the low prices.

Production within the British Commonwealth formerly came largely from Burma, which for the period 1939–45 contributed 58·3 per cent, the nearest to this being Australia with 14·3 per cent. Now, with Burma outside the Commonwealth, Australia is the top producer, producing about 63·4 per cent of the British Commonwealth total. There is no single large source of tungsten minerals awaiting development that would replace the Burma production, but a steady increase in the overall production of all the British Commonwealth countries would go well on the road to overcoming this loss. Increases in production are however tied to price and demand, and as tungsten ore mining is most sensitive to price fluctuation it is difficult to forecast future production statistics. Given a period of reasonable prices, then the industry may be able to establish itself, reduce mining and treatment costs and so be in a position to operate at lower price levels. In the last two decades the demand has not only been stimulated by the armament industry itself but by the general widespread use of high speed machine tools, and consequently there has been a somewhat steadier demand.

British Commonwealth total production represented 22·3 per cent of the total world production for the years 1905–48. In 1949 it represented 7 per cent of world production.

An indirect picture of the tungsten ore resources of the various Commonwealth countries can be gained by comparing the outputs during World War I and II and as these were times of exceptional demand and price, no effort was spared to explore and develop the ore deposits. Such a comparison shows that Southern Rhodesia, South Africa, Australia, Canada and India, in that order, increased production during World War II, the remainder, the Colonial Territories, New Zealand and the United Kingdom, in that order, showed a decrease. The sharp rises in the case of South Africa and Southern Rhodesia represent the result of major exploration and development of their resources and are significant for that reason alone. Equally important are the decreases, notably in New Zealand, which indicate a working out of the easily won ore. The decrease in the Colonies would be even greater had not deposits in Nigeria and Uganda been developed, for the 1914–18 production came entirely from Malaya. The noteworthy increases shown by Australia, Canada and particularly South Africa and Southern Rhodesia suggest that these four countries now possess the tungsten resources of the British Commonwealth.

In 1949 the British Commonwealth produced 1,134 tons of metallic tungsten, which was 40 per cent of the total United Kingdom consumption of 2,939 tons. It is clear that to obtain anything approaching self-sufficiency British Commonwealth production will have to be at least doubled. Given periods of stable, attractive prices, the Commonwealth should show a steady increase in the exploration and development of tungsten ores that should go a long way to balance consumption. The available estimates of reserves from a few of the major deposits in Australia, Canada and the United Kingdom, total 17,900 measured and indicated tons of metallic tungsten. The total reserves of all categories in these countries are probably twice this amount, and that of the other Commonwealth countries probably the same. Hazarding a guess, the total tungsten reserves of the British Commonwealth may represent 50,000 tons of metallic tungsten.

Vanadium

Vanadium resources of the British Commonwealth are mainly confined to South West Africa and Northern Rhodesia. These areas are the only producers within the British Commonwealth, and together they normally produce the equivalent of about 500 tons of metallic vanadium annually. Since 1950, however, Northern Rhodesian production has ceased, and the sole Commonwealth producer is at present South-West Africa. There are other vanadium occurrences in both India and Australia, some of which hold promise of economic recovery of the metal. In Canada the ilmenite ores carry only a trace of vanadium, while the titaniferous magnetite deposits carry 0·20 to 1·0 per cent of V_2O_5.

The present British Commonwealth sources of vanadium are totally inadequate to meet the present demand and the situation has not been improved by the cessation of vanadium extraction at Broken Hill, Northern Rhodesia, which leaves South-West African vanadium-bearing ores as the sole producing source

in the Commonwealth. British Commonwealth production can be expanded by the recovery of vanadium from such sources as natural petroleum, flue dusts and iron ores. The first source is not large, as the Middle East petroleum is low in vanadium, but at present refinery residues of Curaçao are imported into the United Kingdom and yield about 100 tons of vanadium annually. Both domestic and imported iron ores carry small quantities of vanadium which could be recovered from iron and steel smelter slags but at a cost greater than that of the naturally occurring ores. This, like the recovery of vanadium from flue dusts, is only possible if the demand forces the price to a point where such methods become economic or some emergency makes its recovery imperative.

In the long term a very likely source will be from titaniferous iron ores such as those of South Africa, which contain 1·5 per cent vanadium. A certain amount of interest from that point of view is already being taken in these deposits. Similar deposits in New Zealand consisting of titaniferous beach sands carry a small amount of vanadium (0·3 to 0·5 per cent V_2O_5) which is regarded as a potential source.

NON-FERROUS GROUP

Aluminium

The British Commonwealth is particularly rich in bauxite, the principal ore of aluminium, the chief resources being found within the Colonial Territories in and around the Caribbean Sea, in Jamaica and British Guiana. In other territories, the Gold Coast and Nyasaland in Africa, equally important reserves are known, and there are much smaller ones in Borneo and Malaya. India is by far the most important source of the Commonwealth countries and Australia remains the only other Commonwealth country with significant resources at all.

In addition to the reserves of bauxite themselves, several Commonwealth countries possess large sources of electrical energy, some already harnessed for the purpose of reduction of bauxite and others at present merely potential. Canada is the most outstanding example of developed power sources for the aluminium industry, while the Gold Coast sources are being developed as this is one of the few areas where both power and bauxite are found together. New Zealand, with an important electrical potential, may yet offer a suitable point for the processing of bauxite from the East Indies or Australia (though the latter is already developing its power resources), and the possibilities of the territory of Papua-New Guinea must not be overlooked. Viewing the British Commonwealth as a whole, its resources of both bauxite and the necessary electrical energy to reduce it are ample to sustain a large expansion of the industry. A five-fold increase in total demand for new aluminium is projected for the free world, which is well within the present estimate of reserves of bauxite, although it would call for harnessing of much of the potential electrical energy.

The major producer of bauxite within the British Commonwealth is British Guiana, which is responsible for 93 per cent of the Commonwealth total. The next in order is the Gold Coast followed by India, Malaya and Australia.

Copper

The British Commonwealth resources of copper, which take up no less than 26 per cent of the world total, occur in two major areas, Canada and Northern Rhodesia, with Australia and South Africa following in that order. The present production represents 2·5 per cent of the total metallic copper indicated resources.

Over the last two decades exploration and investigation has maintained the measured and indicated reserves at a steady level, although the comparison of past estimates is difficult for, in the main, past estimates have tended to be less critical of quantitative definitions of assessment. Beyond these indicated reserves lie the inferred reserves of which no estimate is presented, but as exploration proceeds they will furnish the indicated and measured reserves of the future. A comparison of estimates of the past, the percentage they represent of the world total and the percentage the 1950 production represents of the reserves, is shown in Table II.

TABLE II

Year	*Reserves of Metallic Copper*		*Production as per centage of reserves*
	Millions of short tons	*per centage of world reserves*	
1934[1]	28·7	27·4	—
1947[2]	25·5	27·2	2·6
1954	28·2	26·2	2·5

[1]Barbour, *Eng. and Mining Journal*, 1939.
[2]Shea, *Eng. and Mining Journal*, 1947.

Lead-zinc

The British Commonwealth has no less than 30 per cent of the world's lead reserves, and the rate of discovery and development of new fields has tended to increase during the last few years; thus inferred reserves have been slightly increased, and the indicated and measured reserves have remained at least static. The figures presented in this report show that the British Commonwealth had in 1950 approximately 32 per cent of the world's reserves, and the present rate of production could be maintained for twenty-two years.

Estimates based on information at present available indicate that the British Commonwealth possesses 18 per cent of the world's measured and indicated zinc reserves compared with 32 per cent of the world's lead reserves.

The three recent lead ore discoveries are in the North-West Territory of Canada, Nigeria, and Tanganyika; in the last-named production has already

began. Although small lead and zinc deposits occur in India, New Zealand, Pakistan, and Southern Rhodesia, no significant reserves are known.

It must be remembered that the estimates in this report are based on measured and indicated ores and for that reason cannot represent final quantities. The inferred reserves cannot really be computed, but represent a reservoir from which, by advances in metallurgical processes, the indicated and measured reserves are maintained. In spite of this it is important to realize that there have been only three significant discoveries of lead deposits during recent years to offset the static position of the reserve picture, and that future production must continue to come from the already developed areas of the Commonwealth. Broken Hill, in Australia, is one of the best examples, where steady exploration and development over the last fifty years have maintained the measured and indicated reserves at a consistent level. Constant exploration and investigation is needed to keep the measured reserves at a constant level and unless that exploration is undertaken the reserves named soon become diminishing quantities. In the case of both lead and zinc, present British Commonwealth production is about 4 per cent of the measured and indicated reserves whereas in the case of copper it is only 2·5 per cent. This suggests that exploration and investigation may be more vigorous in the search for copper or, and it seems more likely, that the search for new copper resources has proved more successful than that for lead or zinc ores. The latter suggestion is supported by comments in the publications of the chief mineral producing countries.

Nickel

The nickel resources of the British Commonwealth are confined to two countries, Canada and the Union of South Africa. Although nickel is known to occur in Australia, India and Southern Rhodesia, there has been no development in these countries except a small production of concentrates prior to 1939 from Southern Rhodesia. The greater part of the British Commonwealth and world production comes from Canada, which provided 99 per cent of the British Commonwealth total in 1951. Nevertheless the South African production has shown an encouraging increase, having now reached 1,254 tons in 1951.

The reserves of nickel ore in Canada in the form of a copper-nickel ore are large. A new Canadian development has been the utilization of the Lynn Lake (Manitoba) low-grade copper ore, carrying 1·223 per cent nickel and some cobalt values. Because of the non-availability power of and the haulage cost of fuel and fluxes, an entirely new and completely wet ammonia leach process was developed that yields, as a precipitated powder, 99·99 per cent nickel, which is sold and transported in bulk as such. South Africa has large deposits of nickel-bearing ores but they have so far not been able to support a nickel mining industry, largely because of the fact that low grade, but platinum-bearing, sulphides carrying a small amount of nickel occur over a wide area and are at present the chief source of nickel. The nickel is exported in the form of a copper matte and is recovered on refining in Great Britain.

Tin

Tin is one of the great mineral preserves of the British Commonwealth, the major world producer being Malaya, followed by Bolivia and Indonesia. Nigeria is the next within the British Commonwealth, followed well behind by Australia, the United Kingdom, Union of South Africa and Canada, in that order. The British Commonwealth production represents about 42 per cent of world production, and 81 per cent of the British Commonwealth production comes from Malaya.

Since 1945 there has been a steady increase in world production, and in that of the British Commonwealth in particular, the most striking increase being in that of Malaya, which rose from 3,530 tons in 1945 to 63,859 tons in 1952. Total production has always been slightly in excess of normal consumption, although the price has seen some striking fluctuations since 1945. The world's main source, Malaya, has in the post-war years been an area of tension and this has been reflected by panic buying and corresponding panic price levels. These price levels have forced attention to lesser tin deposits within the British Commonwealth with the result that there has been an increase in the small producers in Australia, Canada, the United Kingdom and a number of Colonial Territories. With the completion of government and industrial tin stockpiles, particularly in the United States, the price of tin took a further fall, and this steady drop in price will mean that certain smaller producers are likely to cease operations.

Production costs are rising as the more easily worked alluvial deposits become exhausted, and the difficulties of maintaining the present high level of output will increase. Measured reserves are not large and probably represent no more than fifteen to twenty years' production at present rates, but the inferred reserves, of which there is no quantitative estimate available, are known to cover large areas both in Malaya and Nigeria. It is the exploration and development of these inferred tin-bearing areas that will maintain the measured and indicated reserves at least at their present levels. Apart from the traditional source, Malaya, the British Commonwealth can now look to Nigeria for further important and extensive resources.

Titanium

There has been over the last few years a steady increase in both the amount and extent of research in connection with the production and use of titanium metal and alloys. Many predictions have been made of its future importance and the place it may occupy among structural metals in the next decade or so and certainly there is some indication that such predictions are likely to be fulfilled. World production of ilmenite and rutile, particularly the former, has shown a steady increase over the last ten years, ilmenite production showing the greater increase with rutile production remaining fairly steady. Expressed in percentages, India produces 90 per cent of the ilmenite of the British Commonwealth, while Australia produces 98 per cent of the rutile.

The British Commonwealth countries, except Pakistan, Southern Rhodesia, and the United Kingdom, have large reserves of titanium ores, the chief producers at present being India, Canada, Australia and Malaya. Both New Zealand and South Africa have large reserves of titaniferous ores. In New Zealand these ores occur as sand and dune deposits rich in titanomagnetite, while in South Africa the ores are titanium bearing iron ores, containing intergrowths of ilmenite similar to titanomagnetite.

The Canadian deposits at Lake Allard are the largest in Canada and from the development point of view are the most important in the Commonwealth. Present estimates show 200 million tons of ore representing about 42 million tons of metallic titanium.

Information at present available shows that the indicated titanium reserves of the British Commonwealth are large and on geological evidence the inferred sources are many times greater. The titanium ore resources of Australia, Ceylon, the Colonies, India and New Zealand, representing 52 per cent of British Commonwealth total reserves, are in the form of beach and dune sand deposits that make for easy working and concentrating.

MINOR METALS

Beryllium

Beryllium is a light-weight metal that did not become commercially important until about 1932. Its principal use has been largely as an alloy, chiefly with copper, which is used extensively in the production of aircraft, electrical equipment and precision instruments because of its outstanding ability to withstand fatigue and wear and to conduct electricity under high temperatures. A new use for beryllium is in the field of atomic energy, where it serves as a moderator and neutron reflector, and because of its increasing use in this field information concerning the size of deposits and production statistics is becoming more and more restricted.

The major part of the British Commonwealth production comes from South Africa (including South-West Africa) followed by Southern Rhodesia, a new and increasing producer. South Africa is the world's second producer, next to Brazil, and is responsible for 55 per cent of the British Commonwealth production and about 23 per cent of world production. Beryllium is forecast as being in tight supply over the next few years but a steady expansion of world producing sources is envisaged to reach a 60 per cent increase by 1975. On this basis the British Commonwealth production may reach 4,500 tons.

Germanium

During the last twelve months there has been an increasing interest in the recovery of germanium by the sharp increase in its use by the electrical industry, particularly in semi-conductor devices. The introduction of the semi-conductor triode or transister has emphasized the unique properties of germanium as material for such semi-conductor devices.

Semi-conductors do not constitute the sole requirement for germanium in

the electrical industry. Metallurgists wish to experiment on its replacement for silicon in silicon steels, where it is expected to provide greater ductility, but so far there is little germanium available for investigation, let alone for use in these applications.

The principal source of germanium in the British Commonwealth is the coal of the United Kingdom. The present output of 0·5 tons comes almost entirely from flue dusts accumulating in the producer gas systems of gas works. Supplies of such dust are at present insufficient to meet the demand.

In view of the importance of germanium considerable interest is being taken in the United Kingdom in the possibility of additional sources of supply in the Commonwealth, both from coal and any natural germanium-bearing minerals that may occur in sufficient concentration to allow recovery. It is considered that even small tonnages of such minerals could ease the supply position until greater quantities of the indigenous germanium become available.

Lithium

The falling off in the demand for lithium minerals in the years following 1945 has been arrested during the last few years as a direct result of research furthering the utilization of lithium compounds. This steady increase in the demand for lithium compounds has, since 1947, resulted in a steady rise in the production of lithium-bearing minerals in the United States and, to a much lesser extent, in the British Commonwealth.

The lithium-bearing minerals produced within the British Commonwealth are lepidolite, spodumene, amblygonite, petalite and lithophilite, and the chief producer, South Africa (South-West Africa), is responsible for no less than 94 per cent of the British Commonwealth total. Practically the whole remaining 6 per cent is produced by Uganda and Southern Rhodesia and, since 1951, by Southern Rhodesia alone. The lepidolite is the chief lithium mineral produced within the British Commonwealth, and only minor amounts of amblygonite and petalite are at present produced, whereas spodumene is by far the most important lithium-bearing mineral produced in the United States. Spodumene deposits within the British Commonwealth offer promise of important production should the demand for lithium minerals be sufficient to encourage activity. The most promising prospects for increased production are those of Australia, Canada, Southern Rhodesia and the Union of South Africa. In Australia there are several workable occurrences in New South Wales, Western Australia and the Northern Territory, that will respond to an increased demand and price. The increasing demand has stimulated search and development of spodumene deposits in Canada, and serious consideration is now being given to active production of the important deposits of spodumene indicated in Quebec and Manitoba. The chief Southern Rhodesian deposits occur in the Bikita field, where lepidolite and amblygonite are produced as a by-product of the tin mining and there has been a notable increase in production since 1950. Spodumene and petalite occur in reasonably large masses in this area, while in other parts of Southern Rhodesia lepidolite occurs in possible economic

quantities. On the whole, the reserves of lithium bearing minerals in Southern Rhodesia are moderate and production is responding to the increased demand and price. Present South African production comes entirely from South-West Africa, but in the Namaqualand area of Cape Province the spodumene deposits offer economic possibilities.

Increasing use is being made in the United States of lithium hydroxide in low temperature greases, and it is likely that the use in such a form will be extended in the United Kingdom. No lithium metal is produced in the United Kingdom, the demand of about 5 cwt. a year being met by imports, mainly from the United States. The United Kingdom need for lithium ores is estimated at 1,200 to 1,500 tons annually. In the United States, however, there are indications of a sharp increase in demand arising from post-war research into the uses of lithium and its salts, with the result that the lithium industry is expanding rapidly. Large reserves of spodumene have been investigated and there is considerable expansion in the lithium mining industry. In the United States the largest uses for lithium compounds, in lubricants and ceramics, are increasing rapidly, and in metallurgy lithium is finding new and increasing uses.

Some idea of the potential demand is given by the United States objective of 10 million lb. of lithium carbonate equivalent by January, 1955, which will call annually for 50,000 tons of spodumene of 5 per cent grade. Although the indicated reserves of spodumene in the United States are considered to be adequate for many years, supplies of the other important lithium-bearing minerals are quite limited. As the British Commonwealth demand for lithium compounds increases parallel with that of the United States, so must the market for these minerals, and as the United States is drawing most of its supplies of lepidolite from British Africa it would call for marked increases in the entire British Commonwealth production. British Commonwealth resources are on the whole not yet sufficiently delineated to indicate what production increases could be reached and how long they could be held at the increased level. If these demands are going to be fulfilled then it is imperative that the search and investigation of all possible lithium deposits within the British Commonwealth should be actively pushed ahead.

Selenium

Selenium, next to germanium, is now one of the most sought after of the minor metals because of its important uses in the manufacture of rediffusers and in photo-electric equipment, in addition to other uses in chemical industry. A steady production of selenium has been maintained in the British Commonwealth, more than 90 per cent coming from Canada, where production has been around 380,000 lb. annually, except in 1946 and 1947 when 521,686 and 501,090 lb. respectively were produced; but 1952 showed a drop to 242,030 lb. The demand for selenium is still rising and is outpacing the present production, the greater part of which is directly related to the output of electrolytically refined copper. The selenium recovery capacity of Canada, for example, has never been fully

utilized, and it is obvious that as the quantity of electrolytic refined copper increases so do the anode muds and in turn, selenium.

The remaining Commonwealth selenium production comes from the electrolytic copper refining of Australia and Northern Rhodesia, from which about 1,929 lb. and 9,772 lb. respectively were produced in 1951. In addition to the present recovery process, experimental and development work is now being carried out on a method of extracting selenium direct from the blister or fire-refined copper without electrolytic treatment.

NON-METALLIC MINERALS

Gypsum

Huge gypsum deposits occur in most British Commonwealth countries and in some Colonial Territories, with the result that the local production can more than satisfy the local markets.

The largest producer is Canada, being responsible for 52 per cent of the British Commonwealth production, followed by the United Kingdom producing 28 per cent (including anhydrite), then Australia with 5 per cent and India 3 per cent. The remaining 12 per cent is shared by South Africa, Cyprus, Jamaica and Pakistan, in that order.

New Zealand is the only Commonwealth country with no gypsum deposits at all, and consequently is next to the United Kingdom as the biggest importer of both crude and calcined gypsum. Canada is by far the largest exporter of all forms of gypsum in the British Commonwealth, followed at a distance by Cyprus, Australia, the United Kingdom and Jamaica.

The greatest resources lie in Australia, Canada, Pakistan, South Africa, and to a lesser extent in Jamaica and India. Quantitative estimates that are available merely indicate in most cases the reserves of the areas where some development and exploitation have taken place. In many countries gypsum occurs over many square miles of territory ranging from surface outcrops to occurrences found during oil drilling operations. On the other hand extensive resources are known, as in Pakistan, that are too remote from established communication to be economically important at present.

As a result of the world shortage of native sulphur attention has been directed toward the manufacture of sulphuric acid from anhydrite and gypsum. Within the United Kingdom, the largest importer of sulphur and sulphur-bearing minerals of the British Commonwealth, the anhydrite deposits are capable of satisfying any increased demand resulting from an expansion of the sulphuric acid industry. Only an adequate market for the Portland Cement clinker by-product, however, makes this process economically possible. Other sulphur-importing countries with large gypsum and anhydrite deposits, such as Australia, South Africa, India and Pakistan, are interested in such methods of sulphuric acid manufacture.

Mica

India is by far the most important producer of mica within the British Commonwealth, and here resources, accessibility and working costs, are such

that few other countries are able to compete. Nevertheless, because of the strategic importance of mica, defence stockpiling has, since 1945, maintained price and production in most British Commonwealth countries. Next to India, Canada with extensive deposits is the most important British Commonwealth producer, but largely because of a recent recession in demand there has been some decline in the production of sheet and trimmed mica. There is a small production, both of sheet and scrap, from the pegmatites of the Northern Territory of Australia for stockpiling purposes and this is mainly dependent upon a controlled price. A certain amount of sheet mica is produced in South Africa, which ranks third as one of the more important producers of the British Commonwealth. The British Commonwealth production of vermiculite mica lies at present entirely within South Africa; although deposits are known in Southern Rhodesia, India, Kenya and Canada, and are considered to represent a large inferred tonnage, there has been only a token production from Tanganyika, Kenya and Southern Rhodesia.

In all Commonwealth countries except Pakistan and the United Kingdom, there are mica deposits of varying size and grade. The production of condenser grade sheet mica is mainly confined to India, although it is interesting to note that as an example of the stimulus of war-time prices New Zealand was able to satisfy a local demand for condenser mica, a position that was true of most Commonwealth countries. Production costs are, however, sufficient in most cases to make the development of many of these deposits uneconomic, but it is nevertheless obvious that British Commonwealth reserves of this strategic mineral are for all intents and purposes unlimited.

CONCLUSION

A picture of the size and projected life of any mineral deposit must be ever changing, as a result not only of advances in metallurgical techniques allowing utilization of progressively lower grades of ore, but also of exploration, that is, primary geological mapping, which outlines additional inferred tonnages; these, under pressure of demand, are examined in detail to become indicated, and finally measured, ore of economic significance. Any attempt at an assessment of the mineral resources of a country or group of countries must take into account a large unknown : those parts of the territory that have not been geologically mapped as a part of a regional programme. The primary geological mapping is a long way from completion even in such countries as Canada, South Africa and Australia, where there are large geological surveys and a vigorous mining industry to stimulate. The work is now being speeded up by the increasing use of air photographs and systematic photo-geology, an aid to geologists that reduces routine field work but at the same time increases the indoor and instrumental work considerably. However, it does enable information to be gathered of areas covered in bush and superficial deposits that would yield very little to the field worker. The general effect is an increase in speed and accuracy.

In the detailed picture, the examination of the ore deposits themselves, new geophysical and geochemical techniques are important tools in determining the

structure, nature and extent of these deposits. The geologist is no longer an individual worker—he is a member of a team of specialists; but the primary geological mapping is still the concern of the geologist alone, for here the foundations are laid upon which the team work of specialists is carried out.

The future capital of inferred reserves depends upon the rate and extent of primary geological mapping; thus it is imperative that regional mapping be encouraged and kept at the present steady pace and in places the possibility of an increase be considered. We must not be diverted from this basic aim, the primary geological map, especially of the Pre-Cambrian areas, the prime source of most metallic mineral ores. Speaking in a recent review of a publication on Antarctica, Professor Griffith Taylor urged this approach and suggested that instead of exploring the geology and mineral deposits of that difficult area of Pre-Cambrian, we should explore the shield of Australia and Canada where one can at least *see* wide exposures of rock for investigation.

And finally, should we not sit down and attempt some stock taking of our position, of resources in relation to the demand trends, of the variation in utilization and the other related changes that may take place within the next twenty-five years? This has been done in the United States by the Paley Commission, and surely such a document, with all the inherent imperfections, on the British Commonwealth, would be of value. Its completion and study alone would help to clarify ideas and policy on geological and mineral exploration, which is the basis of development of future mineral resources.

DISCUSSION

SIR SELWYN SELWYN-CLARKE, K.B.E., C.M.G. (Chairman, Commonwealth Committee): In a gathering of experts like this it takes a great deal of temerity for a person like myself to get up, but I should like to add a point to certain of the Chairman's opening remarks. He mentioned the interest which this Society has always taken in geology. I should like to quote some extracts kindly provided by our Secretary, Mr. Cleveland-Stevens, which go back to 1759 and 1754. One extract reads as follows: 'The money paid to foreigners, for large quantities of potash used in our manufactures, being very considerable, the Society promises to give to the person who shall on or before the second Wednesday in December, 1760, import into any one port in England, from any of His Majesty's Colonies in America, the greatest quantity of potash, not less than fifty ton, nearest in goodness to the best foreign tpotash: the quantity landed to be ascertained by certificates under the hands of the Collector and Comptroller of the Customs, and the quality to be ascertained in such manner as the Society shall direct'. The premium for that was to be £100. In one of Mr. Willett's diagrams you may have noted that there was something like 210 million tons of potash deposits recently discovered in Yorkshire.

The other interesting reference to these premiums offered by this Society relates to cobalt. If you remember, cobalt, like potash, is apparently in unlimited supply throughout the British Commonwealth. This extract reads as follows: 'Cobalt having been already discovered in some parts of this kingdom—for producing specimens, not less than ten pounds in weight, for the best in quality, to be produced on or before the 15th day of January next [that is to say, January 15th, 1755] with satisfactory certificates of the place where found, and reasonable assurances that it may be obtained in quantity, the sum of £30'.

Just to disclose my ignorance still further in this matter, I should like to put one question to our Lecturer, because it is just possible there are one or two others who are as ignorant of geology as myself. What is the very great importance that mica possesses?

THE LECTURER: Mica in the electrical industry, particularly condenser grade mica—very pure mica free from iron stainings, having a high dielectric constant—is an integral part, and at present a non-replaceable part, of practically all electrical radio, radar and electronic equipment. It is the condenser grade mica that is the strategic mineral.

The other mica, poorer grades of sheet mica, is much commoner and occurs widely throughout the Commonwealth; but it is the condenser grade which is the critical one in times of shortages as in 1939–1945. That is the one that, as I cited in the case of New Zealand, we were able to produce for the local radio industry, and I presume the same applied to Australia and South Africa. Otherwise, mica progressively going down in grade is used for a number of things, insulation, for instance. Another point is the size of the books. Mica occurs in sheets compressed together; they look like closed books. These books can occur in a variety of sizes from three or four feet in diameter to less than an inch square. The size of the sheet coupled with the purity has considerable bearing on price. India is one of the producers of high-grade sheet mica.

SIR EDMUND TEALE: I should like to congratulate Mr. Willett on his very comprehensive survey and also on the emphasis he has put on the importance of stocktaking, which, with ever changing conditions, calls for constant revision. He has indicated how the United States has led the way in this respect, thus keeping more or less up to date with the position of their mineral resources. As one who has had a good deal to do with the search for minerals in the Colonies, I can remember how frantic was the search for certain strategic minerals during both world wars. As usual we were not prepared, but it is hoped that the outstanding example of the United States with respect to thorough and up-to-date stocktaking of their mineral resources will be followed by the United Kingdom and the Commonwealth. The work that is being done by Mr. Willett is most encouraging, and indicates moreover how valuable such information can be in directing future investigations.

There is another aspect of the importance of minerals from a strategic point of view. Many years ago the late Sir Thomas Holland, who was Director of the Geological Survey of India, published a paper in which he claimed that if the United States and Great Britain were to combine in controlling important minerals, a major war could be prevented. That view, unfortunately not applied, was probably valid at the time when Germany was the menace. Now with Soviet Russia in the picture the situation is very different. It is, no doubt, still true that the United States and the United Kingdom with the Commonwealth have together a sufficiency of all the important and vital minerals essential in time of war, but it is also probable that Soviet Russia is equally self-sufficient. Unfortunately, we do not know definitely what the mineral resources of Russia are.

I would like to ask Mr. Willett if he has any inkling as to what particular deficiencies, if any, Russia suffers with respect to strategic minerals. If such knowledge were available it would be a very valuable guide for future action in time of trouble.

THE LECTURER: I do not think there is much I can reply to that question. I think my knowledge of strategic minerals of Russia, their deficiencies and their abundances, is probably not even as good as the questioner's. We both have access to the same information, the daily press.

I have a recollection of having seen somewhere—I cannot quote the authority—

that tin and tungsten were two problems. I was rather surprised at tungsten being a problem. I am still a little hesitant to suggest they are major deficiencies, because, coming back to the beginning of my lecture, Russia has a large part of the Pre-Cambrian Shield. Siberia is relatively unknown geologically; from time to time there must be major mineral discoveries in that territory. I cannot envisage a large area of Pre-Cambrian rocks not being abundant in minerals. The same applies within the free world; Brazil is a relatively unknown area, but the minerals coming out of Brazil appear to occur on a large scale, for example, large quartz crystals.

MR. G. VIVIAN DAVIES: I should like to ask our speaker whether there is any possibility —I do not know how it could be done and I do not know whether his department could do it—of insuring that the mineral resources of the Commonwealth are secured for the benefit of the Commonwealth as a whole. I have in mind a case where I understand an American company, the John Mansville Company, I believe, has taken a lease on a very large supply of vermiculite. Although, no doubt, we can get the use of that mineral, the profit on it will obviously go to America.

The other point I should like to raise is the absolute prohibition by India of the export of a certain mineral; I cannot remember the name at the moment. It occurs to me that with the present loose Commonwealth set-up it may be possible for a country like India or South Africa, in time of national emergency, or shall we say Commonwealth emergency, to say that they will not let a mineral like tungsten out of the country. That is a problem which will have to be faced, if other parts of the Commonwealth are going to adopt this attitude.

Lastly, I do not know whether Mr. Willett mentioned the question of asbestos. I am rather interested to know what the reserves of asbestos are.

THE LECTURER: I do not think I can express any great opinion on the first question, as to whether we should prohibit nations outside the British Commonwealth developing our mineral resources or trading in them in the normal manner. I personally think it would be a very difficult thing to do and short-sighted because after all we do live by trade. The development of mineral resources should be more often in our own hands; too frequently we have had to call in the United States to develop our mineral resources.

India's prohibited exports are minerals associated with atomic energy, monozite and beryllium. The statistics of both are not published and export is prohibited. India is a republic within the framework of the Commonwealth and does not occupy the same relationship with the United Kingdom as, say, New Zealand or Australia.

The third question was to do with asbestos. There are large deposits of asbestos throughout the British Commonwealth associated with the large ultra-basic and basic intrusions of South Africa; as also is chromite. The basic intrusions of South Africa carry asbestos, as do those of Southern Rhodesia, Canada, India and Pakistan. Usually the large deposits are governed by access, which is the important factor of their development. The unfortunate thing about geography is that often our large deposits are too far away from the centre of use or the port of export.

MR. U. BALIOL SCOTT: To what extent have we made progress in recent years on the co-ordination of statistics, both production-wise and on consumption, as between the Empire, the United States and the other countries of the free world? The International Materials Conference, as I understand, has completely folded up now. To what extent had they got really workable, usable statistics while the Conference was in existence? If they had any, is that organization still in being and who is running it and how is it working?

THE LECTURER: On the question of co-ordination of statistics, I notice my friend and colleague Mr. Howling in the audience, who probably can talk with much more

authority than I can as he is responsible for the compilation of the Colonial Geological Survey's annual volume of statistics on mineral production.

The British Commonwealth itself expresses its production and consumption—particularly production—in a variety of terms; we do not even agree among ourselves. For example, Southern Rhodesia, South Africa and Canada all use short tons; Australia, New Zealand and the United Kingdom use long tons. When speaking internationally, you find many countries use metric tons. The United States use short tons domestically and metric tons internationally. It is quite all right when you definitely state the unit you are working in, otherwise it leads to much work in converting to a standard unit.

I think there is room for co-ordination of statistics and presentation of statistics, but the matter was discussed at the 1948 Geological and Minerals Conference in London here and it was decided to approach the Commonwealth Conference of Statisticians with a request that the statisticians investigate the position and see if they can bring about some suitable method for the presentation of mineral consumption. The answer was that the mineral people did not quite know what they wanted themselves and so the statisticians were unable to do anything about it. We are still at that stage. As far as I can see, we all present statistics as we like them. It does lead us into quite a lot of unnecessary calculation, but provided our units are clearly expressed I do not think it is a serious matter.

I know that does not completely answer the question, but I do not think I can without a long discussion.

MR. T. D. WEATHERHEAD, O.B.E.: Many people talk of the great need for assessing the mineral resources of the Commonwealth and for increasing their exploration in order to make sure we have sufficient reserves for the future; but is there a policy behind that, or it it just wishful thinking? As one speaker said, we are always unprepared whenever a war comes. Is it not true that the Government usually assumes that it is up to the mining companies to carry out exploration as they are going to make use of the deposits and are presumably going to make a profit, and that very often the companies turn round and assume that it is the Government's job to carry out the basic geological survey? Is it not also true that, within the time we have available to find out what minerals are available in the unexplored areas, no geological department, however big, could complete the job in time?

Is it not, therefore, better to look at what Newfoundland recently did when facing such a problem? When Newfoundland took over the management of its own affairs there was no geological survey of the territory and the Government realized that they would not get private companies to come and take up concessions on the basis of a blank map. But if the Government took the risk of having a preliminary geological survey carried out at their own expense, then companies would probably take the risk if they considered the geological evidence warranted it. The Government therefore used a private organization to prepare a geological map of some 5,000 square miles. This was completed in two years using all the modern techniques of exploration, with the result that nearly the whole of that area was taken up in concessions by private mining organizations and the Government was paid back hands down for the money it had laid out in basic exploration work.

THE LECTURER: I think the action of the Newfoundland Government would work very well in a compact territory and where there are concerns with the necessary staff and equipment to undertake such a proposition; but I do not think there are the staff or concerns available in the mining and geological consulting houses in this country to carry out such work in, say, the British Colonial territories. I agree that no expansion of any geological survey is going to produce within two years a geological map; I mean a primary geological map of one mile to the inch.

You have to train your men and it does take some time for a new geological survey to become productive. I think the Colonial Directorate would bear me out there; only now are they feeling the full benefit of their big expansion after the Second World War. The difficulty with any government survey, I think, is that it must be frequently diverted from its primary aim of geological mapping to *ad hoc* work. It cannot help it; it is a servant of the community and must act as such. It requires quite a strong personality in charge to resist the attempts to divert the attention of the survey on to what are relatively minor, although at the time extremely important jobs. It requires a lot of knowledge to hold that balance between *ad hoc* work, or applied geology if you like, and regional work on the other hand.

I think that if the regional work is pursued vigorously—it is a function of the geological survey to produce a picture of their territory which would attract the mining houses because of the nature of the geology displayed on the map—people would enter with their more detailed techniques to tackle what they might think are attractive deposits. It is that little area of no man's land, where regional work ends and where the detailed work on mineral resources starts, where official Government agencies, private mining houses and possibly the oil companies, fail to meet; it is that little gap that we have to close.

I do not think it is my place to discuss policy. I can have no policy on this matter, nor would anything I say influence policy in that direction. I could add here in connection with my suggestion, that we have something of the nature of a Paley Report in this country. Every time I look at that Report I feel ashamed that the British Commonwealth is merely mentioned as a subsidiary. I am not giving away secrets here. There has been quite a lot of discussion in a number of ministries here at quite high level on undertaking something along those lines. The matter is in front of a number of people, and I think they are conscious of its need and value.

SIR EDMUND TEALE: I could amplify what Mr. Willett has said, because it is quite definitely the policy of the Colonial Geological Surveys to give special attention to regional mapping. If Dr. Dixey were here I am sure he could say more about it. It is significant that in 1947 there were about 58 geologists employed; by 1953 I think it had risen to 195. With this great increase of staff there is naturally much speeding up of regional mapping, which should encourage private enterprise to follow up the evidence provided.

THE CHAIRMAN: You have already shown your appreciation to the lecturer by your close attention during the lecture and by the applause with which you greeted the lecture when it was concluded and indeed by the questions and interest that has been shown in the general discussion. Obviously it is proper that I should offer formal thanks on your behalf for what has been an extremely interesting lecture and to congratulate Mr. Willett, if I may, on dealing with a very wide and complicated subject within the limited time.

The vote of thanks to the Lecturer was carried with acclamation; and, another having been accorded to the Chairman, the meeting ended.

COLOUR TELEVISION BROADCASTING

A paper by

C. G. MAYER, O.B.E., M.I.E.E.,

European Technical Representative, Radio Corporation of America, read to the Society on Wednesday, 5th May, 1954, with Sir Noel Ashbridge, B.Sc., M.I.E.E., Chairman, Radio Research Board, D.S.I.R., in the Chair

THE CHAIRMAN: It is my very real pleasure to introduce the lecturer, Commander Mayer. You will already know that he represents the Radio Corporation of America, and I think one might say that this Corporation have done more work on this subject of colour television than any other organization in the world.

I know that you are going to hear a lecture of the very greatest importance, and no doubt the company present is specially interested in this subject. I think that we are very privileged in having this opportunity of hearing Commander Mayer give an account of what his organization has done in the States towards the development of this important subject. Colour television is a thing which in the future—I am not saying in the near future, in the middle future or in the distant future, but in some sort of future—is bound to affect us all here in this country.

The following lecture, which was illustrated with lantern slides and a film, was then delivered:

THE PAPER

I feel greatly honoured at the privilege of contributing to your Bicentenary lecture series. The long and distinguished record of the Society undoubtedly gives it full authority to serve as a liaison between the practical arts and the sciences, and there is surely no subject more fitting to its aims than that on which I am to speak to-day. Colour television broadcasting is as much an art as a science, and the day cannot be far distant when many of those present will be able to enjoy colour pictures in their own homes.

The creation of television in colour was a tremendous task, and it is my hope that you will regard this attempt to tell you of its achievement as a small tribute to those whose work and genius made it possible. Within the limits of the time available, I intend to review briefly the fundamental engineering problem, outline the solution adopted in the United States, and discuss the terminal devices whose development was necessary to make colour television a practical reality. Finally, in order to leave you with an impression, better than any words can do, of colour television as it operates to-day, I have arranged to show at the end of my talk a short colour film kinescope recording, produced by photographing the actual images seen on a colour monitor.

THE ENGINEERING PROBLEM

Man has been intrigued with the possibility of transmitting colour pictures from the earliest days of television, and we have known for a considerable time how to do it in a crude kind of way, by methods much too inefficient and wasteful to find a place in broadcasting as it serves society to-day. Mankind progresses, at least in a technical sense, as we learn to understand and make use of the secrets of Nature. Just as sophistication follows experience, and maturity comes as a result of both, so colour pictures follow black-and-white in the orderly development of television.

The basic problem which faced us was to find a way by which colour could be added to our existing black-and-white service—a service which to-day reaches nearly 30 million receiving sets in the homes of the American people. Under these

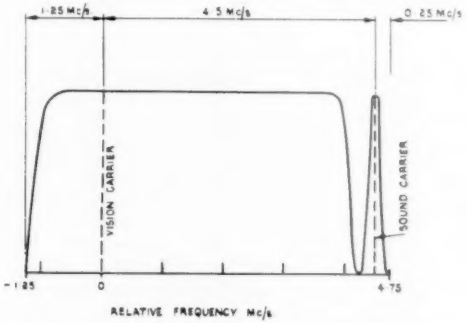

FIGURE 1. *Standards for black-and-white television in the United States: 6 Mc/s channel, 525 lines, 60 fields, negative picture modulation and FM sound*

circumstances it was obviously highly desirable that the transition to colour should be introduced smoothly and without disrupting the good relationships between the broadcaster and the public. The challenge to our ingenuity therefore was to devise a transmission specification which would enable colour programmes to be received in colour on a colour set, and in monochrome on existing black-and-white sets at no additional cost to set owners, and without any changes or added devices. The colour set should also be able to produce black-and-white pictures from standard black-and-white transmissions. A colour television system of this kind is called 'fully compatible', and has been finally adopted. In doing so, however, there was another major problem.

The Federal Communications Commission, which has the responsibility for regulating, in the public interest, the use of the ether in the United States, had established the standards for black-and-white television to operate within the 6 Mc/s channel allocation structure shown in Figure 1. These standards served us well, and as a result television broadcasting developed rapidly. It soon became

evident that to meet the demand to establish new transmitting stations many additional channels would be required. I should explain that frequency bands are assigned by international agreement, and at Atlantic City in 1947 the nations of the world agreed that certain bands, known as Bands I, III, IV and V, should be reserved for television broadcasting. In the United States the twelve channels available in Bands I and III are already completely in use, and the only possibility of providing the needed channels was to extend the allocation structure into the underdeveloped ultra-high-frequency bands above 400 Mc/s, that is, into Bands IV and V. This was done and provided a total of seventy new channels, using the same television standards as for Bands I and III, so that there are now 258 stations operating in these bands, and an additional 130 stations operating in Bands IV and V. A further total of 220 construction permits have been granted in both bands and 250 applications for new stations are pending. Most of the stations can be interconnected for network operations, and the majority of viewers have a choice of several programmes.

I want to digress here for a moment to stress the importance of radio spectrum conservation. Already there is severe congestion, and with the ever-increasing uses of radio services, each interested in establishing its right to an appropriate place in the available ether space, the prospects of relief are slight. We certainly cannot afford to add to the congestion by any wasteful occupancy of the radio spectrum, particularly as its characteristics for transmission differ greatly according to the frequency used.

The following paragraph from a recent authoritative report on this subject deserves to be brought to the special attention of your Society: 'It has become increasingly clear that the spectrum is a public domain which must be conserved most carefully. . . . Radio transmission affects the life of nearly every inhabitant of the globe. Radio is essential to the safety of sea and air travel, carries a substantial portion of all information across international borders, makes the difference between winning a war or losing it, gives entertainment and, it is to be hoped, education to half the population of the world. Add these facts, and it is clear that this intangible public resource, the radio spectrum, requires wise and courageous conservation no less than its tangible brothers oil, coal, minerals, forests and water power'.

As a result of these considerations the Federal Communications Commission took the view that it would not be feasible to provide any extra bandwidth for colour. So if we were to have colour television, a way had to be found of compressing the greater amount of information required into the same channel space provided for black-and-white television. To put it colloquially, we had to find how to pour the proverbial quart into what was thought to be a pint pot. This is sophisticated wizardry of a high order, and much had to be learnt before it could be done successfully.

It will be convenient to examine the solution to our problem in two parts. First we will review briefly the characteristics of sight in relation to colour; and secondly the electrical techniques which make it possible to add the extra information needed to give satisfactory and pleasing television pictures in colour

As you all know, colour printing, painting and colour photography depend on the basic principle that by mixing three suitable primary colours (usually green, red and blue) almost any desired colour sensation can be produced. In these familiar arts we mix pigments or dyes, whereas in colour television we mix coloured light. This has to be converted by a television camera into electrical signals for radio transmission and reconverted to light by a picture-reproducing tube, or kinescope, as it is called, in the receiver, in order to be made visible to the eye. Since the eye is most sensitive to green, less sensitive to red, and least to blue, correct brightness is obtained by mixing the colour signals together in carefully specified proportions.

COLOUR VISION

Most of us are apt, all too often, to take colour for granted in our everyday lives, yet it transforms the commonplace into the beautiful and makes what is humdrum memorable. Without colour life would be drab indeed. Human vision is a complex process involving the eyes and the brain in ways which are far from being fully understood. We experience the sensation of colour in terms of its three major attributes, brightness, hue and saturation. Brightness is a measure of light intensity or 'luminance', and is the only attribute common to both coloured and non-coloured objects. Hue is characterized by the dominant wavelength of a colour, which determines whether it is red or green or blue, etc. Saturation describes the vividness of colours of the same hue, and may be thought of as related to 'purity', or freedom from dilution with white.

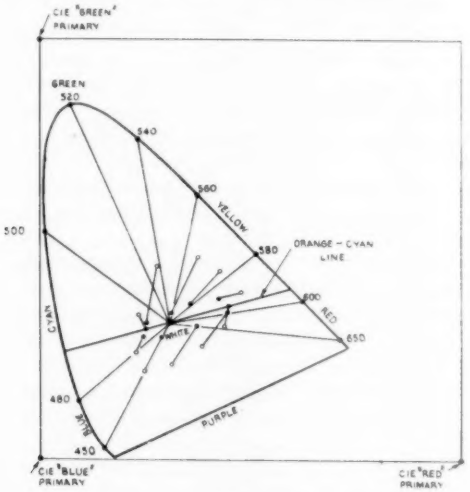

FIGURE 2. *The C.I.E. colour triangle, illustrating colour matching of small pieces from chromaticity data of Middleton and Holmes*

The science of colorimetry has been built up around the principles of colour mixing, and by international agreement the 'chromaticity diagram' of Figure 2 has been adopted, which enables colours to be specified as points on such a diagram in terms of mixtures of standardized primaries. The location of a point completely determines hue and saturation, but indicates nothing about brightness. The visible spectrum is displayed as a closed horseshoe-shaped curve, and all realizable colours are shown on the periphery at full saturation, that is, in going round the periphery hue varies, but saturation stays constant. If we follow a quasi-radial line from a colour at the periphery into white, hue is maintained constant while saturation diminishes.

By suitable choice of primaries, three-colour presentation may be regarded as entirely satisfactory for our purpose. However, as we study the problem we find that while three-colour mixing is necessary for large areas, when the area under examination is sufficiently small, adequate reproduction may be obtained with mixtures of only two colours. This fact emerges as the result of a great deal of new data on vision accumulated in recent years, and perhaps not yet widely appreciated.

In 1945 Willner and Knight reported finding that any colour in a small enough patch can be matched by mixing only two, and not three, primary coloured lights. Two Canadian scientists, Middleton and Holmes, performed the following experiment. They cut small pieces from colour sheets and then asked observers to match the pieces to various large sheets. It was found that the best match was with sheets of different colour from those from which the pieces were originally cut. Their results are shown in Figure 2, where the white dots represent the chromaticities of the original sheets and the black dots the chromaticities of the sheets which gave the best colour match. For the small pieces the chromaticity diagram tends to become a single line; and the two primaries needed for this line are an orange-red and a greenish-blue (called cyan). Another English worker, Dr. Hartridge, has also made a wide variety of investigations on colour acuity in small detail, which corroborate these findings. Further confirmation is to be found in studies of two-colour photography. Clyne notes that although other pairs of primaries are capable of giving black and grey, only the orange-cyan combination can represent adequately the hues of sky, flesh and foliage which are so familiar in nature. Add to these data the observations of sharpness of vision of colour and of brightness contrast edges made in the RCA Laboratories, and we find all the experimental evidence in full agreement that for fine detail areas in a picture, two-colour presentation is entirely adequate. Moreover, the evidence indicates that the eye seems to have greatest acuity for colour differences when they lie along the orange-cyan axis. In passing, it is interesting to note from this that people with normal vision see small coloured objects in about the same way as people who suffer from green/purple colour-blindness see all objects.

Now for what happens when the detail becomes very fine: A. V. Bedford carried out tests several years ago on visual acuity to colour which established that the eye does not see colour at all in the very fine detail of a picture; only the perception

of brightness remains. Actually, the acuity of the eye for red is slightly less than for green, and for blue less than either. The eye is also more sensitive to changes in brightness than it is to changes in hue and saturation. It will be appreciated that as picture detail becomes finer the orange-cyan axis collapses to a point which represents white on the chromaticity diagram. We shall also need to remember that information theory tells us that the transmission of fine detail requires more bandwidth than is needed to transmit coarse (or large area) detail.

In general a transmitting channel can forget what it was doing last in just one-half cycle of the highest frequency passed. Thus a 4 Mc/s channel has the capacity of transmitting a maximum of 8 million fully independent amplitude values per second, although in practice the rate at which information can be passed over a given channel is determined by the prevailing ratio of available signal power to noise power.

At one time it was thought that the transmission of a picture in three colours would involve transmitting three times the amount of information required for a monochrome picture, and would therefore necessitate a frequency band three times as wide, but it has been realized for some time that this is entirely unnecessary. In fact, it has been determined experimentally that the bandwidth for colour information alone can be limited to approximately $1\frac{1}{2}$ Mc/s without the eye realizing any loss of colour in the transmitted picture.

I have a set of pictures, kindly prepared by Dr. Axel Jensen of the Bell Telephone Laboratories, which show the difference between equal sharing of the bandwidth for each colour and optimum ratio of bandsharing. They were made by photographing pictures projected on a screen from an optical projector, consisting of three colour units, by means of which the green, red and blue components of a picture can be accurately superimposed. Control of the optical units is so arranged that the images can be thrown out of focus without changing the magnification of the system, thus maintaining registration.

The amount of optical defocusing is related to equivalent bandwidth of an electrical transmission system, and the projector is calibrated in these terms.

(*The lecturer here showed four pictures, one giving the result of simulating three equal bandwidths of 3 Mc/s in each of the three-colour channels, i.e. 9 Mc/s total bandwidth; the second showing the effect of halving the bandwidth of each channel, to* $1\frac{1}{2}$ *Mc/s; the third again representing 9 Mc/s bandwidth, but with 6 Mc/s green 2 Mc/s red and 1 Mc/s blue; and the fourth showing the effect of halving each of these channels, i.e., 3 Mc/s green, 1 Mc/s red, and* $\frac{1}{2}$ *Mc/s blue.*)

The effect that I want to point out particularly is that, while there is degradation in picture quality as the bandwidth is reduced, the proper apportioning of bandwidth to the three colours according to the principles evolved by A. V. Bedford as in the last two pictures results in better quality pictures than if the same bandwidth is used with equal channels for all the three colours.

We know from experience with black-and-white television that the resolution of the eye for fine brightness detail at normal viewing distance is well satisfied with pictures produced with our normal 525 line scanning process.

This involves a television bandwidth of about 4 Mc/s, which can therefore be regarded as adequate to handle the luminance information required for all conditions of picture detail.

We may now summarize our position by combining these characteristics of vision with our knowledge of electrical transmission. The signal requirements for telecasting in colour may then be stated briefly as follows:

For relatively large picture areas—3 colour (green, red and blue) information, requiring a narrow band of frequencies (about $\frac{1}{2}$ Mc/s).

For relatively small picture areas—2 colour (orange and cyan) information, requiring a moderately broad frequency band (about $1\frac{1}{2}$ Mc/s).

Luminance (brightness) information for all conditions of detail, requiring the same bandwidth as for black-and-white pictures (about 4 Mc/s).

It should be noted also that since nothing is gained by transmitting picture information which the eye does not appreciate, any system which attempts to provide full details of all objects, regardless of their size and chromaticity, should be deprecated as wasteful of spectrum space.

ELECTRICAL TECHNIQUES

This brings us to the consideration of the electrical techniques needed to transmit and receive three separate signals to satisfy these requirements within the framework of compatibility and the prescribed spectrum space.

The sending of two or more independent messages together over one transmission system, yet keeping the messages separable at will, is an old problem in communications. The technique is known as multiplexing, and it is widely used. There are several methods, all requiring greater channel bandwidth than is needed for a single message. The method favoured for multiplexing the two chrominance components is by time division, which involves sharing a channel on a time basis by providing synchronous switching arrangements at the transmitting and receiving ends of the circuit.

In applying this method to colour television, an advantageous switching arrangement is to produce two carriers of the same frequency displaced in phase by 90 degrees, each of which can be independently amplitude-modulated simultaneously to produce a single resultant carrier of the same frequency. The in-phase or I-signal is made to carry colour saturation information, and the quadrature or Q-signal carries information as to hue. The particular method of modulation used results in double-sideband transmission and suppression of the carrier. This becomes the chrominance subcarrier which is conveniently added directly to the main picture carrier. Since the subcarrier is suppressed at the transmitter in the interests of reducing crosstalk, it has to be reinserted at the receiver in order to be able to recover the I- and Q-signals by synchronous detection. This requires the provision of a local subcarrier oscillator in the receiver which is kept at the same frequency and in phase with the corresponding subcarrier oscillator in the transmitter. It is achieved by transmitting a sample of about 9 cycles of the transmitter sub-carrier, which then serves as a reference signal in the receiver to lock the subcarriers together. Interference with other

parts of the television signal is ingeniously avoided by adding the sample or 'colour burst' in the line retrace blanking period which follows the regular horizontal synchronizing pulse.

We have now to combine the chrominance and luminance signals to produce the complete colour signal. The combining of these signals by ordinary side-by-side methods would require a minimum bandwidth of about 6 Mc/s which is still in excess of the video bandwidth available. We have therefore to resort to multiplexing again to compress the information into 4 Mc/s, but in doing so we are faced with additional problems of interference or 'crosstalk' between the signals, which makes it more difficult to separate them cleanly.

This crosstalk has been one of the major transmission problems in the evolution of compatible colour television systems. It can give rise to annoying defects, which take the form mainly of crawling patterns in the received picture. Recent developments incorporated in the RCA system have however succeeded in eliminating most of this trouble.

Many years ago Metz and Grey studied the problem of transmitting two television pictures within a given channel. They discovered that the distribution of energy of signal components due to the process of television scanning, results (for most subjects) in almost all of the energy being bunched around frequencies that are whole multiples of the line-scanning frequency. However, at frequencies half-way between, corresponding to odd multiples of half the line frequency, the spectrum is substantially unoccupied. An additional carrier, carrying independent picture information, can fill these frequency spaces, provided that the added carrier is offset from the main picture carrier by this odd multiple of half the line frequency. The process is commonly referred to as 'frequency interlacing', and results in the carrier and its sidebands being interlaced with the harmonics of the line and frame frequencies. In practice an additional transmitter may be avoided by using a subcarrier modulated with the extra information to be transmitted.

A useful analogy to illustrate the way the gaps in the spectrum are filled is to regard the video channel as a comb, with teeth representing the luminance signal. The chrominance signal can then be considered as the teeth of a shorter similar comb which is placed in such a way that the two combs interlace; the accurate positioning of the second comb being determined by proper choice of the subcarrier frequency.

Another way to look at this matter is to consider it from the point of view of horizontal interlaced scanning. This is known as an important band-saving technique involving the interlacing of two sets of picture elements along each scanning line. If only alternate elements (or dots) of alternate lines are transmitted, in a single field scan, four such fields are required to build up a complete picture frame. Dot-interlacing reduces picture element size and also reduces visibility of flicker. The sequence of interlacing can be so arranged that successive scans are additive, or a cancelling type of interlace can be adopted. Basically, cancellation occurs when provision is made for reversing polarity of the signal between successive scans of each area of the picture. Interference patterns

corresponding to crosstalk between the luminance and chrominance signals then tend to cancel out through the effects of persistence of vision. Dot-interlacing is arranged by ensuring that the picture element signal occurs at a frequency that is an odd multiple of half the line frequency, which happens when the subcarrier goes through a whole number of cycles plus a half-cycle for each frame period. These are exactly the conditions for 'frequency interlacing', thus it is apparent that frequency-interlace always gives rise to dot-interlace and *vice versa*, so that in effect both concepts produce the same result.

We have now covered very broadly some of the main considerations of the system. While there are still a great many details untouched, I believe enough has been said to enable us to specify the general form of transmission signal that will provide a compatible colour television service with optimum spectrum utilization within a 6 Mc/s channel bandwidth, viz:

(a) Full 4 Mc/s video bandwidth signal, representing luminance variations of the subject, transmitted as amplitude modulation of the picture carrier.

(b) Addition of a suppressed subcarrier located within the video band at a frequency determined by 'frequency interlace'.

(c) Simultaneous modulation of this subcarrier by two chrominance components:

(1) I-Signal (requiring about $1\frac{1}{2}$ Mc/s bandwidth) representing saturation, which varies the amplitude of the subcarrier.

(2) Q-Signal (limited to about $\frac{1}{2}$ Mc/s bandwidth) representing hue, which varies the phase of the subcarrier.

(d) Addition of a phase reference signal consisting of a sample burst of the subcarrier frequency transmitted as part of the conventional synchronizing signal.

(e) Sound channel as transmitted for black-and-white television.

Many important details remain to be considered before a specification can be written, but we have time to deal with only a few.

The choice of frequency for the subcarrier is a compromise of several factors. It is desirable to make the frequency as high as possible, so that dot-pattern will be fine and its spurious effects due to imperfect cancellation kept to a minimum. On the other hand a relatively lower frequency increases the bandwidth available for transmitting the chrominance signal. It has been found that for this purpose it is sufficient to provide a band extending in frequency to about $\frac{1}{2}$ Mc/s above the subcarrier frequency. Thus with the available 4 Mc/s video bandwidth, a frequency around $3\frac{1}{2}$ Mc/s is indicated for the subcarrier. The actual frequency is determined by the 'frequency interleaving' principle and by consideration of possible interference with the sound carrier in a receiver.

Experiments have shown that any beat signal between the sound carrier and the chrominance subcarrier (due to insufficient attenuation of the sound carrier in some existing black-and-white receivers) is much less objectionable in the picture if the beat signal frequency is an odd multiple of half the line frequency. This can be arranged by separating the sound and vision carriers by an amount corresponding to a multiple of the line frequency, that is, an even multiple of

half the line frequency. It is not practicable to alter the present sound carrier because of the large number of existing receivers, and therefore to achieve the desired offset operation the line frequency and field rates have been shifted very slightly, actually about 0·1 per cent, which is within the tolerances of the existing black-and-white standard. Non-synchronous operation of the transmitter with the power supply is therefore now essential, but this had already been found necessary for black-and-white television because of network and remote operations. In order to satisfy these conditions the frequency for the chrominance subcarrier works out to be 3·579545 Mc/s (with a line scanning frequency of 15734·264 c/s and a field rate of 59·95 c/s). The spectrum of the transmitted colour signal is shown in Figure 3.

This choice of frequency for the subcarrier results in unequal sidebands, since it allows only $\frac{1}{2}$ Mc/s for the upper while the lower sideband can extend to about $1\frac{1}{2}$ Mc/s below the subcarrier frequency. We have mentioned that in the process

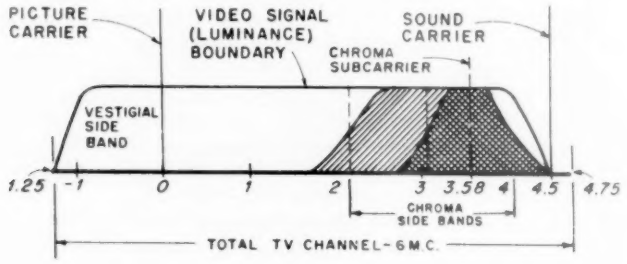

FIGURE 3. *Spectrum of transmitted colour signal*

of interlacing crosstalk can be made self-cancelling, but such unbalance in the sidebands gives rise to additional crosstalk. and means have to be devised to eliminate this. The bandwidth required for large detail areas is less than $\frac{1}{2}$ Mc/s and therefore involves no crosstalk problem. However, as picture detail becomes finer, unbalance occurs in the sidebands, and crosstalk would develop between the components of the chrominance signal. This is prevented by limiting the Q bandwidth to $\frac{1}{2}$ Mc/s so that in picture detail areas where there would be crosstalk if two signals were present, the I-signal only is transmitted and is then, of course, free of crosstalk.

We have emphasized that it would be wasteful use of the spectrum to transmit more information than the eye can see, and it is perhaps equally obvious that we should not transmit the same piece of information more than once. This would happen if each of the chrominance components of a scene to be transmitted contained information relating to brightness as well as to colour. It will be remembered that to satisfy the requirement for compatibility, brightness of the scene is transmitted as amplitude modulation of the carrier in the conventional way. Thus, to avoid redundancy the brightness signal needs to be subtracted

from each of the green, red and blue colour signals. But to transmit four pieces of information when only three are required would again result in transmission of redundant information. The signal representing green-minus-brightness can be obtained at the receiver by subtracting the sum of the red and blue signals from the brightness signal. It is therefore arranged to transmit only signals representing red-minus-brightness and blue-minus-brightness along with the brightness signal. As a matter of interest there is no physical equivalent to the term colour-minus-brightness since the eye responds only to colour accompanied by brightness. In practice the colour-minus-brightness signal is derived by subtracting the electrical value of the brightness signal from the electrical value of the colour signals, using a linear matrix computer. The brightness information is restored at the colour receiver, and we obtain the green, red and blue signals required to activate the 3-colour kinescope or cathode ray tube.

In using these two colour-difference signals to modulate the subcarrier, a refinement is to mix each with the other so that the blue-minus-brightness contains some red, and the red-minus-brightness contains some blue. This does not affect the large detail areas of the picture, but for intermediate picture detail a contaminated or bleeded colour varying from orange to cyan is produced, which results in less noticeable distortion than when a single pure colour is transmitted. The reduction in edge distortion so obtained is due to the fact that the eye is less sensitive to colour in these edges when sharp contrast with the adjoining areas is avoided.

(*The lecturer here showed three pictures, provided by Mr. Hirsch of the Hazeltine Corporation, illustrating the composition of a colour television picture from the luminance and chrominance information. One showed in black and white the luminance information; the second the amount of colour produced by the chrominance signal; the third showed the effect of adding them to each other.*)

Having said all this about television, it is interesting to draw a parallel with the art of painting. One finds that the practice in classical art is first to create form and then to add colour. After laying the base colour, the artist usually paints in the form in monochrome, generally in black or brown and white, paying special attention to the sharp boundaries of the composition, and afterwards adds the touches of colour. This can be observed in paintings from about the sixteenth century onwards and may be contrasted with the work of our modern Impressionist artists who prefer to let form look after itself, and paint in colour direct from the start. In our system of colour television the monochrome signal provides the detail or form, as you have seen, and the colouring is added separately, in what might be regarded as the technique of classical art. Thus we learn from the old, and the new helps to explain what was not perhaps fully understood.

COMPATIBILITY

We have to consider two conditions: first, reception of colour transmissions on a conventional black-and-white receiver. It is easy to see that when there is no colour in the transmission the receiver responds fully to the luminance signal and displays it as usual, with a quality equal (or superior) to that provided by

present black-and-white transmission standards. When there is colour in the original scene the chrominance information is transmitted, but self-cancellation occurs because of subtractive interlace in the colour system, and except for a residual spurious pattern due to non-linear effects in the kinescope, the receiver is not affected by the colour signal. The choice of subcarrier frequency results in the pattern being of such fine texture that at normal viewing distance where the usual scanning line structure disappears, the spurious crosstalk also disappears. The viewer seeing the picture is therefore normally unable to notice any difference from the reception of pictures from a regular black-and-white transmitter.

The second condition is reception of black-and-white transmissions on a colour receiver. This presents no problem since only the luminance signal is present. It is essential, however, that the tricolour kinescope is carefully manufactured and capable of being adjusted to give a white field free from colour contamination due to misregistration or improper convergence of the electron beams. When properly used such a tube gives black-and-white pictures equivalent in quality to those received on conventional black-and-white receivers.

COMPLETE SIGNAL SPECIFICATION

The complete signal specification for colour television broadcasting was recommended to the Federal Communications Commission by petitions submitted by RCA in June, 1953, and shortly afterwards by the National Television System Committee, representing the radio industry. The practicability of the proposed specification had been checked by extensive field testing, and altogether the colour effort involved the co-ordinated teamwork of the most highly skilled electronic engineers and scientists in the United States. The work represented many thousands of engineering man-hours, and the expenditure in pioneering research and development by RCA alone amounted to more than £10 million.

After witnessing demonstrations, and with due consideration of all the factors involved, the Federal Communications Commission decided to adopt the industry recommendations, and in December, 1953, established the technical standards for compatible colour television which are now in force.

No system is perfect at the beginning. We know that the initial cost of receivers is high, and that there are certain inadequacies, none however sufficient to spoil the enjoyment of seeing pictures in colour. Any limitations may be regarded as due to apparatus and not as inherent in the signal specifications. This was recognized in the following remarks which appear in the FCC final colour television decision:

> The proposed colour television signal specifications produce a reasonably satisfactory picture with a good overall picture quality. The quality of the picture is not appreciably marred by such defects as misregistration, line crawl, jitter or unduly prominent dot structure. The picture is sufficiently bright to permit a satisfactory contrast range under favourable ambient light conditions and is capable of being viewed in the home without objectionable flicker. Colour pictures can be transmitted satisfactorily over existing inter-city relay facilities and improvements in inter-city facilities may be reasonably anticipated.

The success of colour hinges on mass receiver circulation, and every effort must be made to bring the price down to the level of the mass purchaser. Every effort must also be made to design equipment to minimize the additional interference susceptibility of operations under the proposed specifications.

History has demonstrated that American industry is capable of devising practical and economical equipment on a mass production basis. We have the assurance of the industry that the enormous engineering and production ingenuity at their command will be focused on these remaining problems.

TERMINAL DEVICES

The FCC standard for colour television is the result of an evolutionary process going over many years of systems and equipment development. We can describe here only briefly the devices used at the terminal ends of the system, namely the arrangement for colour pick-up in the camera and the tri-colour kinescope in the receiver.

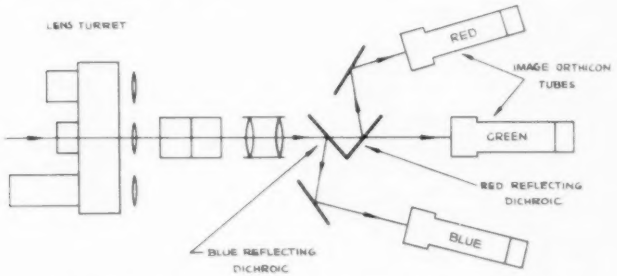

FIGURE 4. *Arrangement of RCA three-tube television camera*

The straightforward type of camera uses three light-sensitive pick-up tubes of a type known as the image orthicon. This tube is in regular operation for black-and-white television broadcasting, and possesses the high sensitivity required for colour. The optical arrangement used is shown in Figure 4. It will be seen that an image-dividing system splits the real image formed by the objective lens into the three colour components by means of dichroic mirrors. These are specially prepared glass plates which are colour selective and can be made to transmit one colour while reflecting another. [*At this point the lecturer demonstrated the properties of dichroic mirrors.*]

Precision controls are provided to ensure identical scanning patterns in the three pick-up tubes, so that electronic registration of the images can match the registration of the optical system. Extensive field experience with this type of camera has proved it to be a reliable means for the transmission of high fidelity colour television pictures.

Thus each pick-up tube in a camera sees its appropriate colour image and produces corresponding electrical signals. These are transformed by suitable studio equipment into the luminance signal, which modulates the transmitter

in the usual way, and into the colour signal which modulates the chrominance subcarrier. Of course, it would greatly simplify the camera to have only a single tube. Methods of doing this have been under investigation for some time, and recent experiments with a tricolour pick-up tube developed in the RCA Laboratories have proved very promising. Although much work remains to be done, the basic principles have been established as well as the feasibility of manufacture, so that we can expect to have a compact tricolour tube camera capable of replacing the present-day three-tube camera.

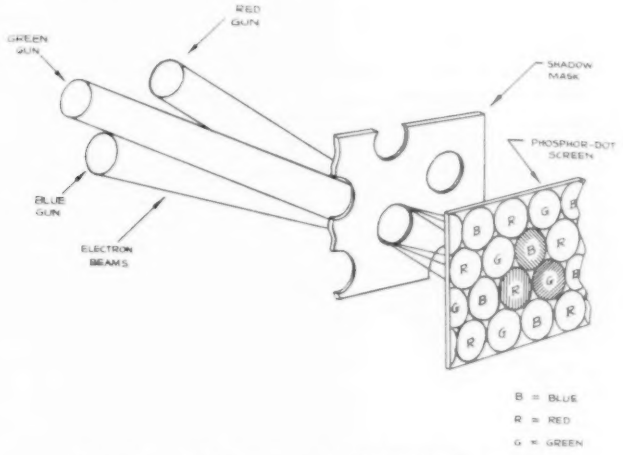

FIGURE 5. *Gun arrangement in RCA tricolour kinescope*

We turn now to the device which translates the electrical signal back into light, so that the eye may see the reproduced colour image of the original scene. Early receivers used three kinescopes with optical filters and mirrors for superimposing the three images. Such an arrangement was far from ideal, and special efforts were made to develop a single tube capable of giving natural colour reproduction. As a result of the ingenuity of our engineers, several different types were evolved, out of which the three-beam tricolour shadow mask tube was chosen for initial product development and manufacture.

In this type of kinescope the phosphor viewing screen is composed of an orderly array of small closely spaced phosphor dots arranged in triangular groups of three deposited accurately on a glass plate. Each dot of the trio is a phosphor which emits either green, red or blue light according to its characteristics when excited by an electron beam. Three separate electron guns provide the beams which activate the phosphor dots and determine their brightness. A metal shadow mask containing round holes equal in number to the dot trios is interposed between the electron gun structure and the phosphor dot plate. The geometry

of the parts is arranged as in Figure 5 so that electrons from the red gun reach only the red-emitting phosphor dots, and similarly the electron beams from the green and blue guns strike only the dots corresponding to those colours. Thus the colour signals controlling the electron beams produce independent pictures in the primary colours. Because of the small size and close spacing of the dot pattern, each trio blends into a single picture element with the result that the eye sees a full colour picture, a 15-inch tube of this type having nearly 600,000 dots, each approximately 0·014 inch in diameter, and giving a 12-inch wide picture. The dot structure, at normal viewing distance, is less visible than the usual scanning line structure, and the tube adequately meets the requirements for black-and-white standards.

(*Here the lecturer demonstrated by a large scale model the operation of the shadow mask tricolour kinescope.*)

There has been steady improvement in colour kinescope performance, evidenced by increased light output, better colour rendering, registration, etc., and also in methods of manufacture, so that the tube now in production gives most excellent and pleasing results. There is no doubt, however, that because of the prevalence in America of receivers with larger black-and-white kinescopes, it is necessary to produce large colour tubes. Preparations are therefore in hand for the production of a similar 19-inch tube which will incorporate still further improvements to simplify manufacture and increase efficiency. The 19-inch tube gives a picture about 15½ inches wide and has over a million dots. This is expected to be followed next year by the demonstration of a 21-inch tube of rectangular form, using a different principle of operation capable of giving still brighter pictures.

The colour tube is really the heart of the system, because its cost mainly determines the cost of the receiver and therefore the price which the public has to pay to see pictures in colour. Everything else may be regarded as of secondary importance. Active development is therefore going forward in many places to bring down the cost of the colour kinescope, and the success of this effort will largely determine the rate of development of broadcast colour television.

(*At this point the lecturer showed an RCA tricolour kinescope in action.*)

In conclusion, you will no doubt be interested in knowing the present state of colour television in America. Colour programmes are being radiated by the NBC station in New York several times a week, and the programme time will be gradually increased. These programmes are available for network operation. Colour equipment is in production, and stations and studios in many parts of America are being equipped to broadcast in colour. RCA has offered to modify existing RCA transmitters free of charge, and its broadcasting subsidiary, NBC, is making available colour programme time without extra charge, so that sponsors can gain experience in the use of this new medium.

Colour receivers and tricolour kinescopes are in production at a rate of several thousands a month, and receivers are now on sale to the public at prices around $1,000 (about £350). It is estimated that the demand for sets will exceed the

supply this year and next year, and that by 1957 the industry will be selling about three million colour sets annually, rising to five million annually in 1958. To install and maintain these colour receivers, which have something more than twice the complexity of a black-and-white receiver, service engineers are being trained in large numbers. Already over 30,000 have attended special 'colour clinic' courses conducted in sixty-five major cities.

Coast-to-coast radio relay circuits have been equalized for colour and are in regular use. Many more such transmission circuits will be available shortly so that by the end of 1954 over one hundred stations across the country will be interconnected for network operations in colour, and colour signals will be within the range of 75 per cent of the nation's homes.

Before closing I want to express my grateful thanks to all those who have assisted in the presentation of my lecture—especially to the British Broadcasting Corporation for the loan of the demonstration apparatus, and to the National Broadcasting Company for all the trouble they have taken in preparing and sending over the colour film which you are about to see. This consists of short portions of three programs recorded during January and February of this year in the NBC television studios in New York, and presents popular American artists.

The recordings were made by Mr. E. D. Goodale on Eastman 35mm negative colour film from which release prints on Eastman colour positive stock are made for distribution. The colour signal was reproduced on a triniscope monitor made up of three 10-inch kinescopes with green, red and blue phosphors and two dichroic mirrors for colour combination. This arrangement was necessary to obtain the highlight brightness of about 200 feet lamberts required for adequate and proper exposure of the colour negative stock or for commercial Kodachrome film. The film camera was a normal type as used for black-and-white recording, fitted with a 72° shutter and 4-inch lens set at an aperture of f2.3 to f3.5. The composite colour signal was decoded and the individual green, red and blue outputs fed directly to the three kinescopes.

My talk has been about American television, but colour in Britain cannot be far away. That is a British problem to be solved in your own way with due regard to television standards, available frequencies and the economics of broadcasting. You may be certain, however, that the friendly co-operation existing between our two countries ensures that our experience will be available when you are ready to put the 'u' into 'color television'.

(*The colour film was then shown.*)

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DISCUSSION

MR. K. W. COLLIN: How have the Americans overcome the interference problem of automobiles? I noted that on the screen it was very inconspicuous.

THE LECTURER: Elaborate field tests were made in the development of the colour television system which we have been discussing, and no difference was found between

its susceptibility to impulse interference compared with the normal black-and-white service. There is a difference between the American standards and the British standards in this respect in that in America we have negative modulation, which means that in general the ignition type of interference tends to cause a black spot, whereas over here you have positive modulation, where the interference tends to cause a white spot. We believe your white spot is more noticeable than our black spot.

MR. G. B. TOWNSEND: Could the lecturer indicate the new principle involved in the 21-inch colour kinescope that he mentioned?

THE LECTURER: I am afraid it is a little premature at this moment to discuss or describe it to you in any detail. As you know, there is a great deal of work going on by numerous organizations in America to produce a better tube, and when I say 'better' I mean a larger and cheaper tube. There are many ways of going about that, which are under investigation and development.

MR. J. N. BARRY: I noticed that on numerous occasions during the showing of the film, and also on at least one of the stills, there was colour fringing, particularly towards the edges of the picture. Could the lecturer indicate whether that was a fault of the actual system, or purely of the tube itself?

THE LECTURER: That is an apparatus limitation due to the particular tubes used. There is nothing inherent in the system which need cause that kind of misregistration.

MR. R. G. HULSE: Has sufficient experience of home use receivers been obtained to know whether or not one has to be an expert to be able to keep them performing reasonably?

THE LECTURER: I think there has been sufficient experience with the numbers of sets that have been put into use. In fact there are no difficulties in keeping the receiver in adjustment provided the signal is satisfactory, and the viewer need be no more expert for a colour set than for black-and-white. The only additional knob you have to control is for chroma, which enables each person to adjust the vividness of the colours to suit his own taste.

MR. G. VIVIAN DAVIES: I should like to ask the speaker if one can use a smaller tube for projection of colour television pictures, in the same way as you can for black-and-white television. If so, would it reduce the cost?

THE LECTURER: One of the earlier ways in which colour television pictures were shown was to do just that, because it requires a considerable amount of development to produce a tricolour kinescope such as the shadow mask type. The obvious and simple way is to take three tubes, using a green, a red and a blue phosphor tube, and mix by projection on a screen. The problem is then one of registration plus the difficulty of obtaining sufficient transmission of light from whatever lens or mirror system you might use. But whether projection sets will prove satisfactory and cost less than direct-view when larger tricolour kinescopes are in mass production is something no one can answer to-day.

MR. J. L. SMITH, O.B.E.: Can the speaker tell us how registration is secured across the whole of the flat face? It would seem that it would require a spherical face to allow for registration.

THE LECTURER: It is achieved by dynamic control of the beam while it travels across the face of the tube. In other words, the convergence of the electron beams through the apertures of the shadow mask is controlled dynamically, in such a way that the focal length of the electrostatic converging lens is made to vary as a function of the deflecting angle.

MR. H. J. LOMAS-CLARKE: Is it correct to assume that the expectation of life of a tricolour tube approximates to a third of that of a tube fitted with one gun and one heater cathode arrangement?

A second point then arises. If this is true, is it being followed up in the United States by some arrangement for rehabilitating these tubes and repairing them?

THE LECTURER: There is no reason why it should be one-third. You can envisage each phosphor behaving like a black-and-white phosphor and being subjected to the same bombardment from the electron beam that a black-and-white phosphor is being subject to from its single gun. If the phosphors are equivalent, there is no reason why the life should be any shorter.

MR. H. J. LOMAS-CLARKE: My point was that you have three entire gun assemblies, each of which contains, I presume, its own heater-cathode arrangement, and I believe a large proportion of failures of tubes as we know them is due to a deficiency in the heater-cathode gun assemblies. Is it a fact that each gun does have its own cathode and heater?

THE LECTURER: Yes, but that is no reason why the colour tube should be expected to have an appreciably less life than the black-and-white tube, and with improved cathodes we shall do better.

As regards your second point, rehabilitation of colour tubes, that is not something which has become a factor yet, because there are not enough of them in service, and it will depend on the policy adopted by the different companies that sell such tubes and on the type of receivers which use them. Some designs of tubes will perhaps lend themselves more easily for being rehabilitated than others; it will certainly be more difficult than with black-and-white tubes.

MR. ERIC GOLDSCHMIDT: Could Commander Mayer indicate how far any British group, including the B.B.C., has indicated its desire to avail itself of these facilities which RCA has developed?

THE LECTURER: No, I am afraid I cannot, but I can tell you this: we have always enjoyed close co-operation with the B.B.C., and whenever they have been visiting the United States we have been very glad to show them the work going on in our laboratories on colour and in black-and-white; we welcome their visits, and likewise, they welcome us when our engineers come to Britain. I think we enjoy excellent relationships with the B.B.C., and with the members of your industry here. But as to what they are doing on colour television I must leave that for them to tell you.

MR. RAYMOND E. COOKE: In view of the firm stand which is apparently being made in the United States to restrict the bandwidth to 6 Mc/s during transmission, is it unlikely that there will be an increase in the vertical definition available by increasing the number of lines during the next few years? That is to say, are some European standards of 800 lines and so on rather premature? Is there, in fact, going to be a world trend towards restricted bandwidth?

THE LECTURER: In my opinion, from our studies of the characteristics of the eye and of television systems in general, I should say there is no point in going beyond the standards which we have found satisfactory for domestic broadcast television.

As I have said during my talk, the radio spectrum space is a resource which has to be carefully guarded. Any attempt to increase the frequency spectrum utilized for broadcasting purposes for supposed advantages, like a higher number of lines, which in fact cannot be appreciated under the conditions in which pictures are seen in the average home, is wasteful use of the spectrum. There ought to be a criminal court at which engineers and others who advocate the use of more spectrum space than is needed or can be justified can be brought to book.

With the standards that we have, the 6 Mc/s bandwidth television channel is in our opinion entirely adequate to give pleasing and satisfying pictures, both in black-and-white and in colour, in the home. The advocates for higher standards will

have to justify them, and I do not believe they are necessary for domestic television. It would be wonderful and a great benefit to viewers everywhere to have a common world standard for television, but that subject involves issues too broad to be discussed here.

THE CHAIRMAN: It is now my very pleasant duty to propose a vote of thanks. In doing so, I should like to make one or two very brief remarks. I think you will agree that Commander Mayer has summarized to an amazing degree the work of a number of extremely eminent scientific and engineering workers over many years. He has had the task of trying to describe the work of all these engineers in the space of a little over an hour. I am sure you will agree that this was a feat which is very difficult to perform, and which he has in fact performed with the greatest possible skill.

We have had a number of questions on the subject of colour television, but it seems to me that the audience is largely made up of research workers, or people very near to research workers—shall we say, development engineers. No one seems to have raised the question as to what is the value of the addition of colour to present-day black-and-white television services. I have been wondering about that for the last three or four years at least, and I have changed my views somewhat in the last few weeks. That was as a result of a visit—not the first, by any means—to the United States. I had the advantage of seeing colour television demonstrated by RCA engineers. In particular I saw a transmission which was an ordinary programme, theoretically intended for the public, but one has to admit that there are not a great number of receivers out yet. It was a transmission such as the B.B.C. might do of some public function in London, but in this case it was a celebration in connection with what is known as the Easter Parade in New York. This was partly taken from inside the Waldorf Astoria Hotel and partly outside in Fifth Avenue, and it went on for quite a considerable time, about an hour and a half. The transmission was excellent, and I was tremendously impressed by the results which were obtained; but I was much more impressed by the fact that they had on one side a colour picture and on the other —not too close—a black-and-white picture. I looked at the colour picture for a long time, and tried to pick it to pieces, saying to myself, 'This colour is sometimes all wrong, the sky is green and it ought to be blue', and so on. It was a very brilliant, bright day. Then I thought, 'What about the black-and-white picture, I think I'll start looking at that for ten minutes or so'. In spite of my criticisms of imperfection in colour shading in the colour picture, I got bored with the black-and-white picture very quickly indeed; it seemed flat and insipid. I went back to the colour picture, whether the colours were exactly right or not. That is a thing which I think needs a little thought. I am going to jump all the way and say that sooner or later colour is certain to come; there is no doubt about that. Exactly when it will come in the various countries of Europe, South America or anywhere else, I do not know. But in any case, it is already launched in the United States. I think that is something to think over.

I do not think that Commander Mayer has quite emphasized the appalling difficulties which RCA research workers and development people have faced in this development. I have had some contact with them, I know the difficulties there have been and I know the inherent difficulties there are in the fundamental problem.

I do not want to take up your time any longer. I know we all agree that we have had a really interesting lecture, very ably delivered and very ably constructed, and accompanied by illustrations which have made the whole thing much more understandable than it would otherwise have been. I therefore propose a very hearty vote of thanks to Commander Mayer for coming to us and delivering this lecture this afternoon.

The vote of thanks was carried with acclamation; and, another having been accorded to the Chairman, the meeting then ended.

GENERAL NOTES

MURAL PAINTING BY IVON HITCHENS, AND SOME EXHIBITIONS

There is little reason to doubt that this Society, which can point to Barry's heroic decorations as the most conspicuous adornment of its building and, among its manifold interests, has encouraged large-scale design through every period since, will welcome with especial satisfaction the enterprise of the English Folk Dance and Song Society in commissioning a very large mural painting for the Main Hall in Cecil Sharp House for the sum of £2,000, made possible by Arts Council assistance. The work, measuring sixty-nine feet by twenty feet, which has occupied Mr. Ivon Hitchens for several years, has been carried out on eleven strips of canvas which have now been joined and affixed to a long wall of the hall in the Society's restored house at 2 Regent's Park Road. As the most ambitious achievement of a serious English artist of consequence, it should be seen by anyone who can make the journey.

It might be thought to be a disadvantage that the painting could not be done directly on the wall, for the artist's method of work has given the decoration an appearance of fragmentariness and denied it that continuous rhythmic movement of forms which we associate with great mural designs of the past, and which here seemed most necessary not only so as to unite the whole design but also to repeat, as it were, the dancing on the floor. In fact, since it seemed needful to the artist to keep the middle of the painting more open (because a dance floor tends to become crowded in the centre), and accordingly to put more incident into the flanking sections, the design has been broken up into compartments and the leading lines used simply to enclose each clustered group of details—not always consistent, one must say, in their mode of stylization. The decoration, in short, has rather the appearance of tapestry than of mural painting.

Despite the absence of flow and unity in the design, Mr. Hitchens' arcadian idyll is absorbing, nevertheless, painted in a scheme of woodland blues and greens, relieved by tawny colours and accents of orange. In his easel pictures his paint is normally very fluid, but here the pigment is somewhat dry and chalky with much use of dappled white. His art remains, of course, suggestive and occasionally elusive, and the artist has accordingly prepared a little pamphlet guide to enable the visitor the more easily to pick out the numerous incidents of which the decoration is composed, such as the rustic musicians and dancers among the brakes, a mythical blue bird, the traditional Green Man and Queen of the May, and to the right some wood-cutters and the beginning of urbanization. Such passages are most delicately contrived and, while they preserve a legendary spirit, are in their style distinctly of our day—the stylized dancers on the left, for example, clearly deriving from Picasso. How posterity may judge the decoration no one can predict, but in the meantime, whatever qualifications may be expressed, it must be recognized as a work of considerable contemporary significance and one which the Folk Society did most courageously to commission.

Artistic offerings of any consequence are, at the moment, oddly scattered, and it is seldom that the art critic is called upon to cross London from Regent's Park to the heart of the City. The exhibition of paintings at the Guildhall Art Gallery 'illustrating trends in British Art, 1900–1954', clearly requires attention, though it is unfortunate that the arrangement is unsystematic, and even more a pity that the movements initiated by some English surrealists between the wars, by the Euston Road group some fifteen years ago, and by to-day's young Social Realists are barely, if at all, represented. Nevertheless, a number of members of the old Camden Town group, Sickert, Gilman, Ginner, Spencer Gore among others, are here to remind us of the worth and continuing influence of their English variant of post-impressionism;

and if one forgets, as one easily may, the purpose of the exhibition, there are many interesting pictures that claim attention in their own right.

Back in Bond Street, to which the critic naturally gravitates by inclination and custom, there is a languid, end-of-the-season air. At Matthiesen's Gallery there is an excellent, but also uncatalogued, miscellany, the works by Degas, Lautrec, and others being neatly and unhelpfully labelled on the wall DEGAS, LAUTREC, etc. *tout court*. It is on such occasions that one realizes the value of annotated catalogues such as London dealers normally supply. Any student of art should be able to recognize the quality and generally the authorship of the paintings here, but information about provenance and subject is what all visitors are entitled to expect. What is known of Berthe Morisot's sitter, the sketchily painted young woman in a green coat? Is the evidently early painting by Courbet of a woman depicted against a sombre landscape a precocious student's excursion into mythology? Curiosity is unsatisfied. Yet as one leaves this pleasant little gallery after surveying so many delightful (and sometimes unexpected) things, it occurs to one that the very mystery that surrounds these waifs and strays of dealerdom tends to make them linger the more vividly in the mind's eye.

NEVILE WALLIS

OBITUARY

MR. REGINALD MARSH

We record with regret the death in Vermont of Reginald Marsh, at the age of 56. Mr. Marsh, after an education at Yale University, studied under K. H. Miller, in New York. He became noted as a marine painter, and it was perhaps this that gained him the commission to decorate the New York Customs House. He was also a painter for the theatre and a magazine illustrator, and in the latter capacity he acted as a war artist for *Life* during the Second World War.

He was elected a Fellow of the Society in 1947.

CORRESPONDENCE

CRAFTSMANSHIP AND THE MACHINE

From P. A. RICE, LAMPLANDS, EAST BRABOURNE, ASHFORD, KENT.

In the course of the stimulating lecture which is recorded in the *Journal* of 16th April, Dr. Nikolaus Pevsner had occasion to deplore the effect on the Society's policy of the 'loathing' felt by William Morris for the machine. That the whole idea of mechanical mass production was alien to Morris's conception of the nature of art is beyond dispute; but whether the Society's activities were unduly influenced by his teaching is a different question. And assuming, as I think we may, that the answer matters, let us first hear what the accused himself has to say about the complex problem of design in modern industry: 'Set yourselves as much as possible against all machine work; but if you must design for machine work, at least let your design show clearly what it is. Make it mechanical with a vengeance and at the same time as simple as possible'. In other words, craftsmanship every time when you can; machine work, good and proper, when you cannot. To which Dr. Pevsner replies: 'No flirtation with period escapism. Grace, yes: decoration, yes, but let them be wholly of this age of ours'. Clearly there is agreement here as to method; the real difference is in a matter of outlook. Morris was a traditionalist, and I need hardly

point out that, so far, no great artistic movement in England has been wholly of its own period. Were Wren and his successors who grafted the latest thing in Greek or Roman antiquities on to the hybrid English stock guilty of period escapism? In a sense I suppose they were, and there are probably few of us who do not feel that they were justified in the result. No flirtation, if you like; no subjection, à la Gothic Revival, of sensibility to mere sentiment, but to demand of any designer, outside the region of pure mechanics, an absolute belief in such a present as this is surely to ask for a good deal. The marriage of true styles from age to age is a natural process in artistic evolution; and without a little of the old wine to give body to its novel ingredients, the work of the contemporary designer is likely to be contemporary and nothing more.

Dr. Pevsner has spoken of Charles Voysey as having gone some way in bridging the gap between the Morris Movement and the machine. That may well be so; nevertheless, I am inclined to think that Morris' true interpreter in the field of industrial design was more probably William Benson, a disciple of his later years who, according to *The Times* obituary of 9th July, 1924, 'preferred to approach his subject as an engineer rather than as a hand-worker; to produce beautiful forms by machinery on a commercial scale, rather than single works of art'. Moreover, when it comes to the point, it is often difficult to say exactly where, in a manufacturing process, craftsmanship ends and machine work proper begins. Certainly some of the looms used by Morris were in the nature of true machines, however primitive, and from what I once saw of it, I should say that the work of the men who operated them was essentially mechanical.

It is true, of course, that the Merton and Hammersmith products were sold to those who could afford to buy, even if they did not always know how to use them; but it seems to me that here Dr. Pevsner is unduly emphasizing the element of contradiction in the difference between a theory which demanded popular art and a practice which virtually denied it. At all events, it is evident that in spite of the lavishness of his own artistic propensities, Morris himself was under no delusion as to the need for austerity in the world outside his peculiar province; thus in condemning the Victorian use of terra-cotta, he concluded: 'I cannot abide it I must say, and I will tell you why. It is used chiefly for ornament, and I am rather inclined to think that of all things that are not wanted at present, and especially in London outside a house, the thing that is least wanted is ornament. I think one ought to pitch one's note rather low and try to get the houses to look solid and reasonable, and to impress people with their obvious adaptation to their uses'. Solid and reasonable, no doubt, but something more than 'machines to live in'; it is only when the machine becomes a fetish, when the concrete-mixer is preferred to the bricklayer as a matter of artistic principle, that the rift between the traditional and the Corbusian school of thought really widens into a gulf.

From the lectures on 'Art and Industry' one thing clearly emerges: the object of their author's multifarious activities was to put the clock on, not back. Except in his deliberate excursions into romantic literature, Morris was never an escapist. His approach to art was fundamentally realistic, and the small but significant body of his topical work as a writer is infused with the fighting spirit of Browning's optimism. The total and temporary eclipse of the crafts under a merely materialistic regime he did indeed consider as a hideous possibility, but to the end his confidence in the ultimate issue remained unshaken: somehow and sooner or later there would, there must be, if life were to be worth living, a renewal of the vital and immemorial relationship which the craftsman had established between the works of man and that which the piety of an earlier age had been content to attribute to the 'admirable workmanship of Almighty God'. And unless I am mistaken, such a renewal has in fact already begun, though perhaps not in the way that Morris anticipated. Yet it was this same 'dreamer of dreams' who once wrote: 'Men fight to lose the battle and the thing that they fought for comes about in spite of their defeat and when it

comes turns out to be not what they meant, and other men have to fight for what they meant under another name'. It is a paradox which at once explains and justifies the movement of which he was leader.

To the author of *The Earthly Paradise*, art was nothing more nor less than 'the properly organized labour of all men who make anything'. For that was his definition of a term which, even in these days of industrial design, is commonly used in a much less imaginative way; and I believe that the great craftsman's final attitude to the momentous changes of the nineteenth century may also, with advantage, be defined in his own words:

> 'The century which is now beginning to draw to an end, if people were to take to nicknaming centuries, would be called the Century of Commerce; and I do not think I undervalue the work that it has done. Its work has been good and plenteous but much of it was roughly done, as needs was; recklessness has commonly gone with its energy, blindness too often with its haste; so that perhaps it may be work enough for the next century to clear away the rubbish which that hurried work has piled up.
>
> 'You of this great and famous town, for instance, which has had so much to do with the Century of Commerce; your gains are obvious to all men, but the price you have paid for them is obvious to many—surely to yourselves most of all. I do not say that they are not worth the price; I know that England and the world could very ill afford to exchange the Birmingham of to-day for the Birmingham of the year 1700; but surely if what you have gained be more than a mockery you cannot stop at those gains or even go on piling up similar ones. What remedy can there be for the blunders of civilization but further civilization? You do not by any accident think that we have gone as far in that direction as it is possible to go, do you—even in England I mean? When some changes have come to pass that perhaps will be speedier than most people think, doubtless education will grow both in quality and in quantity; so that it may be that as the nineteenth century is to be called the Century of Commerce, the twentieth may be called the Century of Education'. And finally, in words which embody the whole message of Morris' teaching, 'You cannot educate, you cannot civilize men, unless you can give them a share in art'.

So much for the future. Meanwhile, however, the position was fast deteriorating; under the combined assault of the Gothic Revival and that peculiarly modern phenomenon, the jerry builder, the essential relationship between art and nature was becoming increasingly unreal; in the flourishing partnership of science and the machine it had, as yet, no recognized place. In such circumstances, under conditions which to some extent persist to this day, is it not possible after all, that the Society was justified in following Morris' lead in keeping alive the fading spark of craftsmanship, even at the expense of a little delay in the development of mechanical design? At least the question is worth asking.

At the present time, in our own prophetically named Century of Education, we must face the fact that the economic condition of most of the surviving crafts is precarious. In the production of standard goods, the machine is usually the answer; but there remains the special job—it may be in so simple a matter as the making of a door frame—for which the use of skilled hand-work is not only desirable from an æsthetic point of view, but actually cheaper, in which the carpenter can beat the machinist at his own game. Let us then be up-to-date within reason. Let us not be unduly elated by the æsthetic potentialities of the machine, considerable as these may be; but let us rather be grateful for the small mercy of the twenty stonemasons who are to be employed in the rebuilding of Coventry Cathedral, regarding them, not by any means as the remnant of a dying race, but as the thin end of a wedge that will one day open the way by which the craftsman may come back into his own.

SHORT NOTES ON BOOKS

PAINTERS OF THE VICTORIAN SCENE. *By Graham Reynolds. Batsford*, 1953. 42*s*

The greater part of this book is taken up by reproductions of some hundred Victorian paintings illustrating the life of the period. These are accompanied by notes on the artist, amplifying, where necessary, the story each picture tells. In the text, Victorian *genre* painting is discussed as a whole.

SILHOUETTES. *By Raymond Lister. Pitman*, 1953. 12*s* 6*d*

This is an account, by the Librarian of the Royal Society of Miniature Painters, of the practical details of drawing silhouettes. There is also a short history of the art, which is far older than the date of its eponym, Etienne de Silhouette, would indicate.

ENGLISH WEATHERVANES. *By A. Needham. Charles Clarke, Haywards Heath*, 1953.

This book contains drawings of eighty-one English weathervanes, accompanied by short accounts of their situation and history. It is preceded by a short history of weathervanes and a note on how to make them.

BOULLÉES TREATISE ON ARCHITECTURE. *Edited by Helen Rosenau. Alec Tiranti*, 1953. 21*s*

The complete text of E. L. Boullée's *Architecture, essai sur l'art* is here published for the first time, with notes and a foreword. This was written at the end of his life, in the 1790s, and contains his philosophy of architecture and projects for several monumental buildings; fifty-five of Boullée's drawings are reproduced.

PICTORIAL COMPOSITION. *By J. K. Popham. Pitman*, 1954. 17*s* 6*d*

The aim of this book is to teach the art student or amateur painter the technique of composition in painting and drawing. The main principles are set out in clear language and illustrated by more than one hundred drawings by the author.

THE ART OF SIGNWRITING. *By B. Hearn. Batsford*, 1953. 21*s*

This practical guide to sign painting has been written by a man with forty years' experience of the craft. He covers all the practical points of writing on a variety of materials and the book is illustrated with examples of popular taste in lettering.

THE SOCIETY'S EDUCATIONAL EXHIBITION, JULY, 1854

The ten issues of the Journal *from 14th July, 1854, onward were almost wholly taken up with reports of lectures delivered at the Society's Educational Exhibition. Extracts from these may be published later, under the heading* 'From the Journal of 1854', *but the following account of the exhibition as a whole, taken, with permission, from* The Times Educational Supplement, *is prefaced as an introduction.*

The purpose of the exhibition was to increase the public interest in education and to let it be seen how children were taught in foreign countries. Most of the Continental countries, North America and some of the Colonies were persuaded to send material. A detailed classification was drawn up in advance by the Society, but it appears to have broken down under the unexpectedly large number of exhibits.

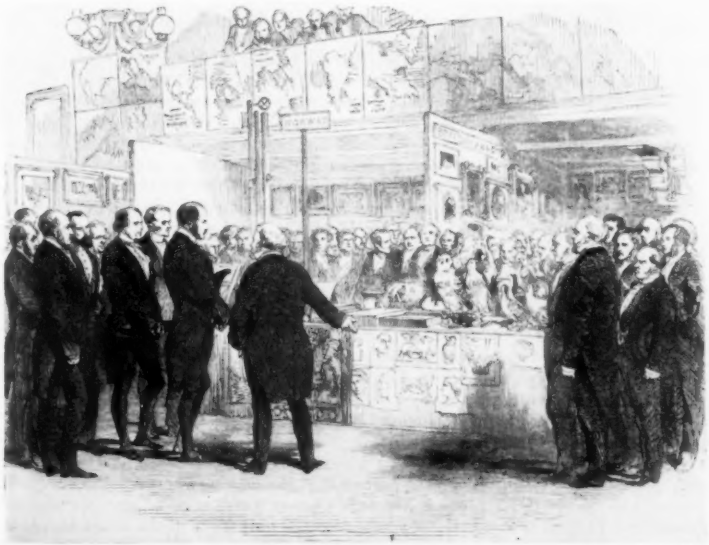
The exhibition was opened on July 4 with a *conversazione* attended by the Prince Consort and '1,200 gentlemen more or less connected with educational literature'. The Prince arrived at 9.15, the *Daily News* recorded, attired in full evening dress, 'and gave a most patient and minute inspection to the various articles'. His desire that something as good and as cheap as the Viennese coloured lithographs of insect and vegetable life should be produced in England was noted by the *Morning Chronicle*.

Over 60 papers were read by eminent educationists in connection with the exhibition.

The Rev. Dr. W. Whewell, Master of Trinity College, Cambridge, delivered the first, and he arrived at an appropriately embracing definition of education as 'the process by which the individual is made a participator in the best attainments of the human mind in general—with what is rational, true, beautiful and good'. The subjects of the other addresses indicate the perennial preoccupation of schoolmasters: the influence of examining as an instrument of education, rewards and punishments, inspectors and schoolmasters, the training of the will, and (true to the practical character of the Society of Arts) the warming and ventilating of schools.

The *pièce de résistance* was a set of cabinets used in the education of the Prince of Wales containing specimens illustrative of cotton manufacture, of fishes, crustacea, and marine plants, and of vegetable products used in commerce. Books outnumbered all other articles. The publishers had stalls and it is interesting to see how many of their names, if not their stock, are to the fore at book exhibitions to-day. Private persons also exhibited their text-books and charts in large numbers, like General Sir Charles Pasley, the object of whose *Practical Geometry* 'was to enable commissioned officers and others, who themselves had but little knowledge of the subject, to teach the men under them the principles of geometry'. Its value to schoolmasters was implied rather than stated. The Reading Reform Association (causes change little) displayed its books on the phonetic method; and there were even 'boxes of letters for the "Look and Say" method of teaching to read'.

There were hundreds of foreign books. The *Daily News* observed that among the American books 'visitors will find many treating of oratory in the most scientific manner, a circumstance which may probably account for the wonderful flow of eloquence so frequently exhibited by American visitors at our public celebrations'.



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The Prince Consort's visit to the Educational Exhibition: from the Illustrated London News *of 1854*

[Crown copyright: Science Museum photograph

The educational collection at the South Kensington Museum in 1859

For the rest, it was a remarkable miscellany of articles, from drawing pins, supplied by the National Society, to a 'Model of a Self-acting Trough for flushing Closets invented by the late Rev. W. Farish, Jacksonian Professor in the University of Cambridge'. There were models of extinct animals made by Mr. Waterhouse Hawkins, including a miniature lechthyosaurus with an attachment of mirrors so that the whole animal could be seen at once. France contributed a working model of a steam engine with the casing made of glass. There was 'Smith's Small Model of Jerusalem, in case, £1 1s.'; an apparatus for the production of musical sounds by the combustion of hydrogen gas, 3s.; the Rev. Henry J. Bigge's hypocaust for warming schools; globes, orreries, planetaria by the dozen; something (what is not explained) called a talantograph; and, perhaps most incongruous of all, 'A small volume entitled "Worthies of the Working Class and their Friends" by Saxe Bannister'. Perhaps it had been left behind by an early visitor, put by an attendant on a stand, and included in the revised catalogue.

One section was of specimens of children's work—writing and drawing, of course, dolls' dresses made by children in the ragged schools, knitted pincushions, a pair of clergyman's bands embroidered by a pupil teacher, and a loaf of bread made by a girl aged 12 years six months in Lawton Industrial School, Cheshire.

The exhibition closed after three months, and although the Society of Arts made a loss of £363 on the exhibition, it was adjudged a great success. The Government were persuaded to take over a large part of it at the end as a permanent collection; this went to the South Kensington Museum when it was opened in 1857, which later became the Victoria and Albert. Of all the material only some of the books appear to remain identifiable and these gave its origin to the present Ministry of Education Library, now comprising over 100,000 educational books. This therefore is the library's centenary year and to celebrate it there is a small exhibition now on view at the Science Museum.

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